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PAPERS

OF THE

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EDITORS
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UNIVERSITY OF MICHIGAN

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MICHIGAN MOUNDS, WITH SPECIAL REFERENCE TO TWO IN MISSAUKEE COUNTY

EMERSON F. GREENMAN

IN THE summer of 1925 the University of Michigan Museum conducted work upon two inclosures belonging to it on the Missaukee Preserve in Missaukee County, Michigan. During the course of the investigations, two burial mounds were excavated with results which indicate the presence in prehistoric times of two different cultures in the region. One of the mounds was on the crest of a ridge within 1,000 feet of the smaller inclosure, and the other was on lower land about one and one-half miles to the south. The mound near the inclosures was between 17 and 18 feet in diameter and 2 feet 2 inches in height at the center, measured from the bottom of the shallow trench which surrounded the mound, out of which the material for its erection was taken. This trench was from 5 to 8 inches below the level of the ground outside, and 4 to 6 feet in width. At a depth of 3 feet and 6 inches below the surface at the center was found a male human skeleton, lying southwest and northeast, head to the southwest, the legs tightly flexed so that the bones of the feet were resting alongside the pelvic bones. The left forearm lay across the abdomen, and the right at an angle of 45 degrees to the axis of the trunk. The bones were partially decayed, the ribs, vertebrae and right and left radii having disappeared altogether. The upper end of the shaft of the left femur had been broken during life and mended without being set, which made it about an inch shorter than the right femur.

No artifacts were found with the skeleton, but there were two stones lying in a position indicating that at the time of the burial they had been laid on the chest. In size they were 10

by 9 by 3 inches, and 12 by 5 by 3 inches. The different strata of the mound were disposed in the following order, from the surface downward: first, a layer of dark brown, loose soil, containing pebbles and roots, 1 foot and 10 inches thick at the center of the mound; next below, a layer of black sand and charcoal about 2 inches in thickness and coming to the surface at the perimeter of the mound; immediately below this, a layer of light gray sand, firmly packed and containing few pebbles, varying in thickness from 3 to 10 inches. The outer edges of this layer turned downward to a depth of 2 feet. At the center of the mound there was a cone-shaped deposit of medium-brown, loosely packed sand containing small stones, which extended down through all three of the different strata, at the bottom of which was found the skeleton, about 20 inches below the natural level of the ground. The layer of white sand and charcoal at the base-line of the mound may be the remains of a fire which formed part of the burial ceremony after the body had been placed in the hole and before the erection of the mound, or it may represent simply the original surface of the ground. The cone-shaped deposit of loosely packed sand, with the apex reaching to the skeleton and of the same general consistency as the bulk of the mound above the layer of charcoal, may be taken to indicate that a hole was dug, uncovering the burial, sometime after the erection of the mound. The purpose of this hole can only be conjectured. Some aboriginal vandal may have taken out such artifacts as had been placed with the burial and left the two stones on the chest of the skeleton in their place, or the first burial may have been removed and another substituted.

The second mound, about one and one-half miles to the south, was like the first, circular, with diameters of 21½ and 25 feet, at the center 41 inches above the bottom of the surrounding trench, which was from 4 to 10 inches below the natural level of the ground. Excavation of this mound uncovered a small pile of charred bone fragments 6 inches wide, 9½ inches long and 1½ inches thick, 27 inches below the surface at the center of the mound. About 3 inches above this pile of bone fragments was

a layer of bark 15 inches long by 10 inches wide and one half of an inch thick, which encased a copper "axe," 6¼ inches in length. The bone fragments proved upon examination to be those of an adult human being whose remains had been almost cremated. There was only one fragment, a piece of the proximal epiphysis of the humerus, which rendered certain identification possible. One end of the bark layer containing the copper piece lay under a stone about 7 inches in diameter, and directly over the pile of cremated bones, which was 8 inches to one side of the bark, was a large rock 11 inches in diameter, the top of which was 4 inches beneath the surface of the mound. The bark in which the copper piece was encased was found to be of two kinds, oak and elm. In other parts of the mound were found what was apparently a piece of human rib about 2 inches long, a small round bone an inch long which had probably been worked, two small pieces of psilomelane, a copper-bearing mineral found in Michigan, and two small pieces of flint which show little evidence of having been worked. About 2½ feet from the pile of cremated bones, and at the same level, was found a piece of stone 3½ inches long, 1 inch wide and three eighths of an inch in thickness, which had been worked and smoothed into a shape resembling a small whetstone. Another layer of bark 4 or 5 feet in length at a distance of 3 feet from the bark containing the copper piece may originally have connected with it.

The different strata of the mound occurred in the following order: first, a layer of brown sand, containing pebbles and roots of plants on the surface, from 1½ to 2 feet in thickness, following the curve of the surface of the mound; next below, a layer of black sand and charcoal from 2 to 6 inches thick. The bark encasing the copper piece was in this layer; directly beneath the outer 6 feet of this layer was a stratum of ashes and sand from 4 to 6 inches thick, which descended in places to a depth of 2 feet. Underneath this layer of sand and ashes on the outer side, and of sand and charcoal near the center of the mound, were the fine gravel and sand which constituted the base of the mound, and in the top of which was found the pile of bone fragments, 3 inches below the sand and charcoal layer. The

evidence of fire of considerable intensity seems to have been localized at two points on opposite sides of the place where the cremated bones were finally deposited, at distances of 7 and 8 feet therefrom, and from 2 to 4 feet below the surface of the mound at those points. In these buried fire-pits were found abundant charcoal remains and stones which had been stained and cracked by fire. The small piece of worked bone already mentioned was found in one of these fire-pits.

There is small doubt that the cremation of the body occurred on the site of this mound. A very intense fire of short duration, such as is necessary to cremation of a human body, would leave nothing but fine ashes with little charcoal. That the fire was very hot is indicated by the lack of charcoal remains in the layer of ashes occupying the entire base of the mound between the two fire-pits, in the center of which was found the pile of cremated bones accompanied by the copper "axe." This axe, which showed no mark of fire, was laid beside the cremated remains, encased in its layer of bark, after the cremation had taken place. The two fire-pits, on opposite sides of the mound 11 feet apart, may be interpreted as fire-places in a lodge, very likely made of bark and poles, which occupied the site before the erection of the mound, since they were below the natural level of the ground, and showed evidence, both by this depression and by the thickness of the layers of charcoal in them, of a considerable duration. The finding of the piece of worked bone in one of them strengthens this conclusion. Fire-pits have been found in similar positions on the base-line of mounds in the state of Ohio.[1]

The strata of the surrounding trenches of the two mounds were very different. In the trench of the first mound, in which the complete skeleton was found, was a lens of vegetable mould about 8 inches thick in the middle at the surface. A cross-section of the trench of the mound containing the cremated burial shows at the surface a layer of humus 2 inches thick, next below a layer of clear yellow sand from 1 to 2 inches thick, and then a compact layer of humus 1 inch thick. Under this second layer

[1] Wm. C. Mills, "The Feurt Mounds and Village Site," *Ohio Archaeological and Historical Society Publications*, 26: 321.

of humus was a lens of dark gray sand about 6 inches in thickness, beneath which were the undisturbed gravel and sand. It is of course impossible to arrive at any conclusions as to the date of erection of the two mounds on the basis of these strata, but they may indicate that the first mound was older than the second, since the deposit of vegetable mould in the bottom of the surrounding trench was thicker by 7 or 8 inches. Nothing was found in either mound to indicate European influence.

In the state of Ohio, years of excavation have revealed two radically different cultures. The Fort Ancient culture is characterized by a very limited use of copper, burial in more or less conical mounds, occasionally in dug graves with no mound, interment above or on the base-line, and inhumation with rare cremation. The Hopewell culture is characterized generally by very free use of copper, mounds usually low and irregularly shaped, and often covering remains of wooden structures, and cremation with rare inhumation.[2] Inhumation and cremation are thus in Ohio accompanied by other practices equally different, establishing two cultures with essentially different traits. When one applies this method of culture differentiation to the two mounds in Missaukee County, it seems reasonable to conclude that they represent the work of two different cultural stocks, but one must bear in mind, of course, that there is only one example of each type under consideration. The two mounds have certain points in common, such as general size and shape, vertical disposition of strata, and proximity to one another, but these features would not be sufficient to demonstrate their common origin. The most important difference between them is the fact that one contained an inhumation and the other a cremation. Along with these two types of burial were other differences. With the inhumation there were no accompanying artifacts, while a copper implement was found with the cremation; the site of the mound containing the cremation had evidently been a dwelling site before the erection of the mound, and if this is true, it probably determined the location of the mound; there was nothing to indicate that the

[2] H. C. Shetrone, "The Culture Problem in Ohio Archaeology," *American Anthropologist*, 22: 144.

site of the other mound had been previously occupied, and its location was possibly determined by a desire for good drainage and a sense of the picturesque, as it was on the top of a ridge from which there was a view of the surrounding country for 10 or 15 miles. The proximity of this mound to the two inclosures, which are probably the remains of village sites,[3] leads to the tentative conclusion that it was built by the occupants of these villages, which would be consistent with the lack of evidence that the mound site had previously been a dwelling site. No such inclosures have been located near the site of the mound containing the cremation, which was in a narrow valley between two low ridges.

Not enough work has been done on Michigan archaeology to enable us to establish precisely the limits of the different archaeological groups of the state, but examination of the records in the Museum of Anthropology and of the accounts of excavations in the last forty or fifty years by Gillman, Hubbard and Harlan I. Smith[4] reveals several different types of culture based upon methods of burial. Skeletons are found in a sitting position, in a flexed position, and fully extended, lying on the back. Verbal reports have been given to members of the Museum staff of skeletons in mounds sitting facing each other, in a standing position, and lying on the back in parallel rows in groups of three's, but verification of these reports has not yet been made. There are authentic accounts of cremation for other parts of the Lower Peninsula than in Missaukee County, and it has been found accompanied by copper implements in mounds near Grand Rapids,[5] in the Ayers Mound in the city of Saginaw,[6] in a mound in Fort Wayne,[7] and in the Grattan group of mounds near

[3] W. B. Hinsdale, *Primitive Man in Michigan*, *Michigan Handbook Series*, No. 1, p. 44.

[4] Harlan I. Smith, "Archaeology of the Saginaw Valley," *American Antiquarian and Oriental Journal*, XVI: 106.

[5] Bela Hubbard, *Memorials of a Half Century*, p. 207.

[6] Harlan I. Smith, p. 9 of his Field Notes, now in the Museum of Anthropology, University of Michigan.

[7] Henry Gillman, "*Investigation of the Burial Mound at Fort Wayne, on the Detroit River, Michigan*," Proceedings of the American Association, 1876, p. 315.

Grand Rapids.[8] In addition there are reports of copper implements in mounds unaccompanied by a burial of any kind, but it is probable that in many cases ashes from cremation have been overlooked by inexperienced excavators. On the other hand copper implements have been discovered with complete skeletons and cremation has been found without accompanying artifacts of any kind.[9] A type of burial fairly frequent in Michigan is characterized by the placing of earthen pots, inverted or upright, over the heads of skeletons, or near the hands.[10] And finally, skulls with trephinations both before and after death have been found.[11] Just how far these various practices designate definite cultural groups and to what extent they correlate with the known practices of the historical Indians of this region, is yet to be determined. The differentiation of culture-groups based upon archaeological evidence alone is beset with peril unless the data are complete and voluminous. In the words of Cyrus Thomas, "It is often the case that different modes of construction and burial dependent upon station, condition in life, calling, achievements, etc., are found in the mounds apparently constructed by people of a single tribe or even a single village." [12]

Evidence is accumulating that certain traits of the prehistoric culture of Ohio extended into the Lower Peninsula of Michigan. The copper implement found with the cremation in Missaukee County resembles in detail implements of the same material found with cremated burials in the Edwin Harness Mound in Ohio,[13] and the inside of the sheath of bark in which it lay was lined with what are probably the remains of a textile fabric of some kind in which the implement was wrapped. Around the flaring end of the implement are the remains of a cord or string

[8] W. L. Coffinberry, Coffinberry manuscript, in the Museum of Anthropology, University of Michigan, and Kent Scientific Museum, Grand Rapids, Michigan.

[9] *Michigan Pioneer and Historical Collections*, 3: 297.

[10] Bela Hubbard, *op. cit.*, p. 222.

[11] W. B. Hinsdale, *op. cit.*, p. 85.

[12] Cyrus Thomas, "Report on the Mound Explorations," *Annual Report of the Bureau of Ethnology*, 1890–91, p. 553.

[13] Wm. C. Mills, "Exploration of the Edwin Harness Mound," *Ohio Archaeological and Historical Publications*, 16: 156–158.

of finely woven material which has been completely replaced by copper salts. The copper axes in the Edwin Harness Mound were encased in bark and a woven fabric which was preserved in the same manner. The same is true for copper axes from mounds near Davenport, Iowa.[14] It is probable that when more information regarding the mounds of Indiana, Illinois and Iowa is available, the area represented by these three states and Ohio and Michigan will prove to have been occupied in prehistoric times by people with approximately the same technical culture, a culture which probably had its highest and most complete expression in the general area now comprising the state of Ohio. A list of articles found in the mounds of the Lower Peninsula of Michigan indicating a relationship to the prehistoric cultures of Ohio include mica plates, from the Grattan mounds near Grand Rapids, red ochre, a sea-shell from the Gulf of Mexico (*Busycon perversum* L.), the association of copper implements with cremated remains, copper ear-plugs, "vaults" of logs containing inhumed burials in mounds in Van Buren County, and several pieces of pottery in the Kent Scientific Museum in Grand Rapids which resemble a certain type of Ohio pottery and are not as yet found elsewhere in Michigan. So far as we can rely upon the records of excavations in Michigan in the last fifty years, supplemented by an examination of the articles of copper now in public and private collections throughout the state, there is good reason to believe that the use of copper had attained in Michigan about the same stage of development as that characterized by the Hopewell culture of Ohio, in which copper was freely used both for utility and ornament.[15] Both implements and ornaments of copper are found in Michigan mounds and on the surface of the ground; ornaments of that material, however, are limited for the most part to mounds, as far as the records indicate.

Within historic times Michigan was occupied by various branches of the Algonquin family, Potawatomi, Sauk, Ottawa, Chippewa, Miami and others, and was subject to frequent in-

[14] R. J. Farquharson, "Recent Explorations of Mounds near Davenport, Iowa," *Proceedings of the American Association*, 1875, p. 304.
[15] H. C. Shetrone, *op. cit.*, p. 156.

vasion by members of the Iroquois family, but attempts to show that they erected the burial mounds of the region [16] have been unsuccessful. There are several accounts of Indian "funerals" in Michigan, by eye-witnesses, and burials both above the ground in log "pens" and beneath the surface are described,[17] but no mention is made of the erection of mounds. It is stated in the *Handbook of the American Indian* [18] that the Potawatomi built small mounds over their graves, but the evidence that they did so was not based upon actual observation. It is also stated here that the Potawatomi practiced cremation, which was limited exclusively to the Rabbit gens, but that their method of burial was chiefly that of inhumation. According to Père Sebastian Rasles,[19] a certain division of the Ottawa tribe cremated their dead, while others interred their remains, but according to Bushnell,[20] his account may not be true.

European objects of brass, iron and steel have been found in Michigan burial mounds [21] and it is reported that some of the Jesuit silver, consisting of bracelets and other ornaments, now in the possession of the Museum of Anthropology, was taken from mounds near Cross Village, Michigan, but they are probably intrusive burials and should be so regarded until there is proof to the contrary. All the available evidence points to the conclusion that either the historic tribes of Michigan had discarded the practice of erecting mounds of earth by the time that white people reached this region, or that the mounds are the sole remaining evidence of the occupation of the peninsula by a people who became extinct, or migrated to other regions, before the advent of the Algonquin tribes found in possession of the state by the Europeans.

University of Michigan

[16] Cyrus Thomas, *op. cit.*, p. 659.

[17] *Michigan Pioneer and Historical Collections*, 27:330; 21:297; 18: 571, 574; *History of Livingston County*, 1880, Everts and Abbot Publishers, Philadelphia, p. 238.

[18] P. 291.

[19] *Jesuit Relations*, Editor Reuben Gold Thwaites, LXVII: 154–159.

[20] David I. Bushnell, Jr., "Native Cemeteries and forms of Burial East of the Mississippi," *Bureau of American Ethnology*, Bulletin 71, p. 38.

[21] John T. Blois, *Gazetteer of Michigan*, p. 167.

INDIAN MODES AND PATHS OF TRAVEL IN MICHIGAN: WATERWAYS

WILBERT B. HINSDALE

THERE was more long-distance travel upon the water than overland, except during the months when the lakes and streams were obstructed by ice. The streams brought the primitive hunters into immediate contact with a large quantity of their food-supplies, such as wild rice, fish, and water birds like wild geese, ducks, swans and the waders. The best fur-bearing animals, as beavers, minks, otters, fishers, muskrats and several others, whose skins and flesh were desired, were never found far from the water. In the summer time, deer fed along the banks in search of succulent herbage and protected themselves from flies and mosquitoes by wading to a considerable depth into the water. When hotly pursued, deer would swim into the lakes to escape from their enemies, wolves, dogs and hunters. The Indians made many of their captures of deer by overtaking them with canoes. A great many ancient camp-sites are in the vicinity of navigable streams and lakes. The canoe was an easier and, generally, more rapid means of travel than following the trail upon foot, especially when the family and household belongings were to be moved. One must bear in mind that the streams had a more constant volume before the surface run-off was facilitated by cutting away the forests, draining the marshes and swamps, and clearing out the thickets. With considerable degree of accuracy, we can make out what were the habits of primitive people from the physical surroundings in which they lived. Replace the forests, inundate the old swamps, let the streams meander as they did before the iron ax and spade came

into the land, restore the animal and bird life, replenish the waters with their original numbers of fish, and the problem of how the Indians lived is easy. They themselves were a part of the wild life, an ingredient in the zoölogical complex, or what naturalists call the fauna. In the treatises upon the mammalia of the state, however, the Indians are generally left out, but meadow mice and bears are subjects for extended elucidation.

The Indian's bark canoes and dugouts were narrow and light. Creeks and brooks that are now quite insignificant, enabled the boatmen to ascend, in high water, for miles into places that we should deem utterly inaccessible by boat. For example, Mill Creek, that joins the Huron River at Dexter, was for miles a navigable stream for an Indian. The streams never got so low in summer as they do now and probably not often so torrential either, because the flow of water was more or less retarded by vegetation. Portages were numerous, and some of them very important to the subsistence of the population. The name 'Portage,' given to many of the lakes as well as to several streams, indicates the actual fact that they were in the line of water travel upon which there were carrying places or portages. When the "head of navigation" was reached, it was not much of a burden for the dusky travelers to carry their light canoes upon their shoulders and their scant luggage overland for a few miles to another branch of a river, flowing the other way from the one ascended, but leading in the general direction of the course pursued.

Maumee–Wabash–Little St. Joseph route. — In order to give more completeness to the account of the Indians' transportation routes of this territory, we include a small part of northwestern Ohio and northern Indiana. In ascending the Maumee from the head of Lake Erie to the St. Marys near Fort Wayne, the portage of seven miles to the Wabash is reached.[1] This, in historic and prehistoric times, was an important line of Indian travel. The French used it in going to and from their posts in Indiana. Considerable heavy freight was transported. Teams would meet the boats for the purpose of hauling goods and passengers across.

[1] Map in Cadwallader Colden's *History of the Five Nations*, 1755.

Pontiac's allies and Tecumseh's warriors from the southwest came over these streams. For unnumbered years before that, it was the main line of Indian travel between the lower lakes and the Ohio River and mid-Mississippi regions. By taking the Little St. Joseph at the Fort Wayne junction, canoes could enter southern Michigan. In Hillsdale County portages of only a few miles enabled canoes to slip into the St. Joseph of Lake Michigan or into the headwaters of the Kalamazoo and of the Raisin.

Huron–Grand route. — The Huron River trans-peninsula waterway was very important to both Indians and pioneers. From the Huron, by a good-sized stream not more than forty rods long, the outlet of Big Portage Lake which is upon the line between Washtenaw and Livingston counties, the Portage Lakes are entered. Boats ascended Portage River from Little Portage Lake to the vicinity of Stockbridge in southeastern Ingham County. From this point the carry-over was but three miles to the Orchard, or what was formerly called Otter Creek, the north branch of the Grand.[2]

Mr. H. F. Wing, of Grass Lake, tells the writer that forty years ago he actually paddled across the divide between Portage River and Otter Creek, through the low lands and swamps, without having to get out of his canoe. The Indians, during high water, certainly could also do the same, and the only obstruction from Lake Erie to Lake Michigan would have been rapids and fallen timber.

The following is summarized from Samuel R. Brown in the *Western Gazetteer*, 1817 (pp. 74–75): There are upwards of twenty portages near the Michigan frontier only two of which have heretofore been used by whites. An important one of these was between the St. Marys branch of the Maumee at Fort Wayne, Ind., and the Little River branch of the Wabash and is nine miles long. It was by this route that the French, while in possession of Canada, passed to their forts upon the Wabash and on to the Ohio. Boats not infrequently passed from Lake Michigan into the Illinois and in some instances it was not necessary to

[2] H. C. Carey and I. Lee, *Geographical, Statistical and Historical Map of Michigan Territory*, Philadelphia, 1823.

have their lading taken out. In the winter of 1792–3 two boats (*pirogues*) were detached from Detroit, which passed without interruption from the Huron River, which enters Lake Erie, into the Grand River, which falls into Lake Michigan, by means of the rise at the heads of the two streams.

The Grand, the largest river of the state, afforded communication, by its tributaries, in many directions. One could go directly to its mouth at Grand Haven. At Ada, in Kent County, he could divert to the Thornapple and reach the center of Eaton County. By a short portage near the present site of Charlotte, Battle Creek is entered. Descending this stream in western Calhoun County, where the city of Battle Creek now stands, its confluence with the Kalamazoo opened up a water-route east or west. By leaving the main Huron–Grand channel at Big Portage Lake, in Livingston County, and going up Pinkney Creek as far as conditions of canoeing would permit, it is a carry-over of but a few miles to Cedar Lake in Marion Township, Livingston County, the head of Cedar River.[3] Cedar River unites with the Grand at Lansing in Ingham County. The Maple and Looking Glass rivers, branches of the Grand, as important channels of communication, will be traced in connection with Saginaw River tributaries.

Raisin–Kalamazoo–St. Joseph–Grand routes. — The Raisin has several branches. By the Saline River, which enters the Raisin at the old Macon Reservation in Monroe County, the salt springs of Washtenaw County, where the present village of Saline stands, were reached. At Clark's Lake, southeastern Jackson County, which drains into the Raisin, the land obstruction was not more than three or four miles to the south branch of the Grand. In going directly up the Raisin into eastern Hillsdale County, portages less than a township wide would reach the Kalamazoo entering Lake Michigan at Saugatuck, Allegan County, the St. Joseph entering the same lake at St. Joseph, Berrien County, or the Little St. Joseph connecting at Fort Wayne, Indiana, with the Wabash and Maumee for "points east or west."

[3] Mrs. Franc. L. Adams, *Pioneer History of Ingham County*, p. 483. "Cedar River can be ascended for 25 or 30 miles by boats." — p. 125.

"From the southermost portion of the great bend of the St. Joseph it is only a short four miles across to the headwaters of the Kankakee which, with the Illinois, empties into the Mississippi. In the old days this little neck of land was a famous crossing place, or portage, for the Indians of the south and west on their journeys to the northern wilderness. Once over the divide, by turning to the right they could follow up the St. Joseph to the fine hunting grounds beyond or a short paddle would bring them to Fort St. Joseph, a small French trading post or garrison." [4]

One must not forget the pristine situation of the landscape. Before the forest and brush cover were removed, the depth of water in the channels was more regular and never got so low as it does since the clearing was done and since the swamps were drained and the ditches dug. For example, what the older maps designated as the St. Joseph of the Maumee, a rather crooked stream, is now for miles a straight drain called the Maumee Ditch. The steam-shovel and the woodsman's axe have markedly accelerated the run-off of the surface water which at one time was sufficient to buoy up an Indian's dugout. In many parts of the state, the water table has been lowered as much as five feet and is going down all the time.

In pioneer times, steamboats were operated upon the St. Joseph as far as Three Rivers in St. Joseph County.[5] Navigation companies once promoted steam navigation upon the Kalamazoo. Flat boats came to within two miles of Ypsilanti upon the Huron. Steamers plied regularly upon the Grand up to the Rapids and above the Rapids pioneers did much freighting up to the Maple. Boats carrying two hundred barrels of flour descended the Shiawassee from Owosso to the Saginaw.[6] In early times there were all kinds of canal schemes to connect the natural waterways at the portages so that commerce could reach the inland counties, which led to extensive "wild-cat" speculation.

[4] Clyde Ford, *The White Captive, A Tale of the Pontiac War*, pp. 1–2.
[5] Fuller's *Economic and Social Beginnings of Michigan*, pp. 292–293.
[6] *Michigan Pioneer Collections*, 2: 486.

Grand–Saginaw route. — Canoes could ascend the Grand to Lyons, Ionia County, take the Maple and approach within the breadth of a half-township the Shiawassee in the center of the county of the same name, and descend to Saginaw Bay, going the entire length of the Saginaw River which is really only a continuation of the Shiawassee. The Looking Glass, which enters the Grand at Lowell, Ionia County, practically parallels the Maple to southern Shiawassee County and to Conway Township in northwestern Livingston.[7]

Saginaw–Tittabawassee–Chippewa–Muskegon route. — Suppose one were at the mouth of the Saginaw below Bay City and wished to reach Lake Michigan at the mouth of the Muskegon. He could have done so, a hundred years ago, by boat, with only five or six miles of land obstruction in eastern Mecosta County. *Directions:* Ascend the Saginaw to the Tittabawassee, go up that stream to Midland, divert to the Chippewa River, on to Chippewa Lake in Chippewa Township, Mecosta County. Walk three miles, the guide carrying canoe, to Pogie Lake, same township. The outlet of that lake is a branch of the Little Muskegon. Go with the current. Look out for rapids. Or, if one would wish to arrive at the place where Ludington now stands, by going down the Little Muskegon to its junction with the main stream, he would turn up and ascend as far as the middle of the western side of Mecosta County. Two or three miles' portage to the west would bring him to the Père Marquette River at the mouth of which is Ludington. Again, less than ten miles separates the head of the Chippewa from the Muskegon, main branch, in Osceola County. For boundary between Montcalm and Gratiot counties, take the Pine from the Tittabawassee. There was, at an early day, a line of flat freight boats

[7] "It (the Grand) is navigable 240 miles for bateaux, and receives in its course as its principal tributaries the Rouge, Flat, Maple, Looking-Glass and Red Cedar Rivers on the North, and the Thornapple on the South. It is navigable for steamboats 40 miles to the Grand Rapids, below which it has not less than four feet of water. At the Rapids a canal is constructing; and after it is completed steamboats may go up to the Village of Lyons, at the mouth of the Maple, a distance of 50 miles from the Rapids, without difficulty." — Mrs. Franc. L. Adams, *op. cit.*, p. 126.

projected to ply between Alma, in north-central Gratiot County, upon the Pine, and Saginaw.[8] The Cass River passes through what was a thickly populated Indian district lying east from the Saginaw. Down this stream, according to archaeological evidence, the Indians brought hundreds of chert nodules from which they made arrow points, knives and other edged tools. The Flint River nearly parallels the Cass into the "Thumb" and was used extensively in Indian commerce.

Au Sable–Manistee–Muskegon routes. — Ascend the Au Sable River to the boundary between Crawford and Otsego counties. Carry-over six miles to the swift Manistee and go merrily on to Lake Michigan. Wishing to reach Muskegon Lake and Lake Michigan into which it discharges, follow the south branch of the Au Sable, in Crawford County, to near Higgins and Houghton lakes in Roscommon County. Houghton Lake, the largest inland lake of Michigan, drains into the main stream of the Muskegon.

There were many other minor water circuits that facilitated random travel by the Indians. The Clinton–Huron circuit passed through Macomb, Oakland, Livingston, Washtenaw, Wayne and the northeast corner of Monroe counties. There was a Cheboygan, Mullets Lake, Burts Lake, Crooked Lake connection from Cheboygan to Little Traverse Bay.

Keweenaw–Peninsula cut-off. — A boat of almost any size could, by the Portage Lake inlet from the head of Keweenaw Bay, go to within three miles of Lake Superior. A light canoe made this passage with but a mile of portage, thereby saving eighty miles of travel that would be required by going around the point. The ship canal has now eliminated the obstruction and large steamers cross the peninsula.

Menominee–Sturgeon rivers route between Green and Keweenaw bays. — Foster and Whitney describe in detail the route which they took in the fall of 1848 coming from L'Anse to Green Bay. They remark that the streams they traversed, beside those of this route, had been Indian canoe-ways long years before voyagers came. The crossing from the Sturgeon, flowing into Kewee-

[8] *History of Gratiot county*, 1913, p. 44.

naw Bay, to the Michigamming, a branch of the Menominee, is in Township 48 W., R. 32 W., southwestern Baraga County. This trip required eleven portages around rapids varying from a half-mile to several miles each.[9]

Mr. George H. Cannon says the Wisconsin, which empties into the Mississippi, the Menominee with its branches, emptying into Lake Michigan, the Ontonagon, the Sturgeon and some others flowing into Lake Superior were navigable by bateaux for considerable distances from their sources, while the Indian, with his light bark canoe, could, with ease, overcome hindrances to freight-carrying boats and by shouldering his own make a portage around rapids and other obstructions and set out on the waters beyond. By such means streams were followed to their sources, divides crossed and voyages continued.[10]

In this paper frequent references have been made to the uses the pioneer tradesmen made of the streams. If traders could navigate so far in their scows and bateaux, the narrow, shallow and light craft of the Indians could, and did, go many miles farther.

The following by Dwight Goss is pertinent: "In autumn an entire family, and sometimes two or three families together, would leave the villages and wander up the smaller streams into the forests of the interior for their winter's hunt, and they would generally camp in or near a bunch of maple trees in order that they might make maple sugar in the spring. Indian villages and camping places were almost invariably upon banks of rivers and small streams." [11]

The white mechanic has not invented or perfected an appliance that more nearly fits a need than the bark canoe fitted the needs of the Indian. It could float on very shallow water. It was so light that when a portage or obstacle was reached, it could be lifted out like a basket. Accidents often occurred, for the bark canoe was easily punctured by sharp rocks, submerged

[9] *Report of the Geology and Topography of a Portion of the Lake Superior District, State of Michigan*, Part 1, 1850.

[10] *Michigan Pioneer Collections*, 30: 46.

[11] "The Indians of the Grand River Valley," *Michigan Pioneer Collections*, 30: 172.

roots and other parts of trees. When it was damaged bark, pitch and wattap were at hand for repairs.[12]

The canoe obeyed the propelling and guiding hand more sensitively than a power boat responds to its rudder. Without seeming effort, as a duck directs its course through the water by its perfectly adjusted foot, the Indian men and women directed their canoes by the blades of their paddles.[13] Foster and Whitney remark: "Communication throughout the northwest between distant points is effected almost entirely with the canoe. It serves the same purpose as the ship on the ocean or the camel on the desert." [14]

While it is out of the geographical limits of Michigan, it is interesting to trace the route of Marquette and Joliet from Lake Michigan to the Mississippi by the way of Green Bay, Fox and Wisconsin rivers. The portage from the one of these rivers to the other Marquette calls "2700 paces." Thwaites says, in his life of Father Marquette,[15] "With high water in the Wisconsin, this plain has frequently been flooded, so that continuous canoe passages from the Great Lakes to the Mississippi has been possible." Ordinarily, the portage was a mile and a half. To go still farther afield, for the sake of emphasizing the importance of water communication employed by the Indians, it was possible, and also practicable, for oar-propelled boats to go from the head of Niagara Falls to the mouth of the Mississippi by several routes, and, conditions being favorable, to do so, in some cases, without unloading.

The longest would have been the Huron–Grand route from the head of Lake Erie, to Lake Michigan, skirting that lake along the shore to Green Bay and following Marquette's route to the Mississippi. Then there was the Raisin–St. Joseph route across Michigan to nearer the head of Lake Michigan. From this lake, taking the channel now followed by the Chicago drainage canal to the Illinois river, the way was clear to the Mississippi and, at

[12] Footnote, p. 29, of Foster and Whitney's *Report of the Geology and Topography of a Portion of Lake Superior District*, 1850.

[13] T. L. McKenney, *Tour of the Great Lakes*.

[14] P. 23. [15] P. 186.

high water, continuous without unloading boats. La Salle followed this route upon one of his return trips from central Illinois, reaching Lake Erie by the Huron River. The Kankakee River, from near Chicago, afforded good facilities for leaving Lake Michigan. There is an old portage from the Sandusky River to the head of the Scioto. Probably the most important route was the Maumee–Wabash. The shortest route, which was used in both prehistoric and historic times, and which was controlled by the Iroquois, was to leave Lake Erie, where Cleveland is now situated, ascend the Cuyahoga to near the present site of Akron, follow the Portage Path seven miles to the Tuscarawas, down that stream to the Muskingum, which enters the Ohio River at Marietta, which in prehistoric time was a seat of wonderful industry, as evidenced by the extensive earthworks that existed there.

The intention is to follow this chapter by another upon "Trails."[16]

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[16] Since the foregoing was written the attention of the writer has been called to Franquelin's map of the eastern part of what is now the United States, made in Paris, 1688, upon which is distinctly marked a portage between the Saginaw and the Maple rivers, the Maple being the north branch of the Grand.

ACQUIRED AND TRANSMITTED CHARACTERS IN GREEK LORE OF HEREDITY

EUGENE S. McCARTNEY

THE perplexing question of the acquisition of characters and their transmissibility is at least as old as the Greek civilization. According to one story man acquired his numerous qualities in an extremely casual manner. After all creatures had been molded in clay Epimetheus essayed to distribute the characters with which they were to be endowed, but unfortunately the supply was exhausted when he reached man himself. To remedy this trying situation Prometheus took a small portion of their qualities from each animal and gave them to man. In this way, then, man acquired his complex and composite nature.[1]

Aristotle[2] says that a child resembles its parents in both 'congenital' and 'acquired' characters. This sounds like modern technical terminology, but the translations are accurate and without an added shade of meaning. It was believed that some acquired characters disappeared within three or four generations, but that others became a permanent part of the life-stream.

[1] This story, except as it applies to man, is told at great length in Plato, *Protagoras*, 320 D–321. The only source extant for man's part in the drama is Horace, *Carmina*, 1. 16. 13–16. Cf. Emerson, *History:* "Every animal of the barnyard, the field, and the forest and of the waters that are under the earth, has contrived to get a footing, and to leave the print of its features and form in some one or other of these upright, heaven-facing speakers." According to Christian doctrine mortality is an acquired character of man. See St. Augustine, *Contra Iulianum Pelagianum*, 5. 15. 55 (Migne, *Patrologia Latina*, 44. 815), who thus speaks of the birth of Christ: *Assumens ex illa* (his mother) *etiam mortalitatis infirmitatem, qualis non erat ante peccatum in carne hominis primi, ut esset ista, quod tunc illa non fuit, similitudo carnis peccati.* Cf. Genesis, iii. 22.

[2] *De Generatione Animalium*, 721 b 28–29.

As might be expected, the Greeks were far more interested in these aspects of heredity than were the Romans. There is of course considerable material on this subject in Latin writers, but it is taken almost entirely from the Greek. There do survive, however, records of a few inherited peculiarities among Roman families.

ACQUIRED CHARACTERS

General Influences and Impressions

In the first part of this paper I shall discuss characters that were supposed to be imparted to the child while still within the womb. Pliny,[3] doubtless borrowing from a Greek source, says that a thought passing momentarily through the mind of either parent is believed to mold or blur the resemblance of the child. He notes that there are more differences between human beings than between individuals of the same species of animals, and explains this as due to the quickness of perception in man and to the wide range of his mental activities, whereas there is monotonous uniformity in animals.

It is the opinion of the Athenian in Plato's *Laws*[4] that during pregnancy a woman should be "kept from violent or excessive pleasures and pains, and should at that time cultivate gentleness and benevolence and kindness." The belief in the peculiar susceptibility of mothers to physical and mental impressions at the moment of conception and during pregnancy, which is as pronounced today as it ever was, has given rise to some interesting stories in Greek.

There was an ugly man who wanted a beautiful son. He had a picture painted of a fine boy and told his wife to keep her gaze upon it during conception. According to Galen, she kept both her eyes and her mind intent upon it, with the result that the child to which she gave birth resembled the picture instead of its

[3] *Naturalis Historia*, 7. 52. Compare the opening chapter of *The Life and Opinions of Tristram Shandy, Gentleman*, by Laurence Sterne.

[4] *De Legibus*, 792 E (Jowett's translation). Aspasia, as quoted by Aëtius, 4. 16. 12, says that pregnant women must be kept from fear, sadness and all strong emotions.

father.[5] The Spartans had their wives look at paintings of Narcissus, Hyacinth, Castor and Pollux, Apollo, Dionysus and other models of physical beauty and perfection.[6] Statues might serve the same purpose.[7]

A most remarkable story of this character is that of Persina, a queen of the Ethiopians, who lived in a palace adorned with paintings. In the bridal chamber there were some that depicted incidents in the love-story of Perseus and Andromeda. A daughter, Chariclea, that was born to the royal pair was entirely white. The mother exposed the child in order to escape the charge of adultery, but with the tokens that accompanied it she included a letter to be read by it on growing up. She vowed her love for her daughter and told how during conception she had been looking at a picture of Andromeda, whom Perseus was bringing down naked from a rock. Fearing that she would not be believed if she explained the reason for the whiteness of her child, she pretended that it had died at birth and exposed it.[8]

The belief that the character of the offspring of animals too could be controlled at the moment of conception was quite prevalent. Pictures of beautifully colored horses were shown to mares.[9] Sheep were supposed to conceive young similar to the rams they saw reflected in water acting as a mirror.[10] Before the female pigeon there was displayed an abundance of finely wrought purple garments in order to cause her to produce purple young.[11] Reeds too seem to have been used in an effort

[5] Galen, *Ad Pisonem de Theriaca*, 11 (14. 253–254, Kühn's ed.). This story is told by St. Augustine, *Contra Iulianum Pelagianum*, 5. 14. 51 (Migne *Patrologia Latina*, 44. 813). He took it from Soranus. According to this source, the man was the tyrant Dionysius.

[6] Oppian, *De Venatione*, 1. 358–367: cf. 338–341.

[7] Plutarch, *Moralia*, 906 E; Galen, *De Historia Philosophica*, 32 (19. 328, Kühn's ed.).

[8] Heliodorus, *Aethiopica*, 4. 175–177. The ancients were ready enough to believe such stories by hearsay, even if they did not act in conformity with their belief in a given case. In this instance, however, the romance of Heliodorus would have been spoiled if the infant had not been exposed.

[9] Oppian, *De Venatione*, 1. 331–347. Isidore, *Origines*, 12. 1. 59, says that the horses themselves were brought before the mares.

[10] Isidore, *Origines*, 12. 1. 58.

[11] Oppian, *De Venatione*, 1. 352–357. Isidore, *Origines*, 12. 1. 59, says that pictures of beautiful doves were kept where they could be seen by the doves.

to secure young pigeons of various colors.[12] One will recall the story in Genesis (xxx. 32–42) telling how Jacob outwitted Laban by having sheep conceive with mottled reeds in view. Three of the verses read as follows:

> 37. And Jacob took him rods of green poplar, and of the hazel and chestnut tree; and pilled white streaks in them, and made the white appear which was in the rods.
>
> 38. And he set the rods which he had pilled before the flocks in the gutters in the watering troughs when the flocks came to drink, that they should conceive when they came to drink.
>
> 40. And the flocks conceived before the rods, and brought forth cattle ringstreaked, speckled, and spotted.[13]

Hawthorne makes literary use of the belief that impressions through the eye can affect the physical appearance. In *The Great Stone Face* he recounts a prophecy the purport of which was that "at some future day a child should be born hereabouts, who was destined to become the greatest and noblest personage of his time, and whose countenance in manhood, should bear an exact resemblance to the Great Stone Face." The boy to whom a mother tells the prophecy lives with the expression upon the Stone Face as his inspiration and finally in his old age he comes to resemble it.

"Women in pregnancy are a prey to all sorts of longings and to rapid changes of mood, and some call this the 'ivy sickness.'"[14] The longings are more acute when the child is female, and the women are less contented when they get what they want.[15] According to Hippocrates,[16] when there is a desire to eat coals or earth, the likeness of these things appears upon the heads of the children.[17]

[12] Oppian, *De Venatione*, 1. 349–351.

[13] This story is mentioned by Isidore, *Origines*, 12. 1. 58. See too St. Augustine, *Contra Iulianum Pelagianum*, 5. 14. 51 (Migne, *Patrologia Latina*, 44. 812).

[14] Aristotle, *De Animalibus Historia*, 584 a 18–20 (D. W. Thompson's translation). On this disease, which the Romans called *pica*, see also Galen, 17 B 860; 19. 455 (ed. Kühn); Paulus Aegineta, 1. 1; Aëtius, 16. 10; Soranus, p. 15 of V. Rose's edition. For other references see Francis Adams, *The Seven Books of Paulus Aegineta*, vol. 1, pp. 2–3.

[15] Aristotle, *op. cit.*, 584 a 20–21. [16] *De Superfoetatione*, 18.

[17] "Females during pregnancy have longings for all sorts of food, sometimes for eels, sometimes for wild turnips, or shell-fish, or what not; but

Birthmarks and Monstrosities

Whatever animal women saw or thought of during conception, to such an animal they gave birth; pregnant women were forbidden to look upon such ugly animals as cynocephali ('dog-heads'[18]) and monkeys.[19] At times people said that a child had the head of a ram or of a bull.[20] Lovers of Dickens will remember that Mrs. Harris's husband's brother was "marked with a mad bull in Wellinton's boots upon his left arm, on account of his precious mother havin' been worrited by one into a shoemaker's shop."[21] Similar things are to be found in the health columns of our newspapers. One of my clippings reads as follows: "I am five months pregnant. The other day I felt a pain in my abdomen. Accidentally I put my hand on my stomach, when suddenly a mouse ran across the room. Do you think that will show a mouse on the baby's body?"[22]

Satyrism, a disease in which the face looked like that of a

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no idea prevails, similar to the popular European prejudice, that the non-gratification of these longings is attended with bad consequences to the child, in the shape of marks to disfigure the body." — Shortland, *New Zealand*, as quoted in Lean's *Collectanea*, 2. 110 (*Collections by Vincent Stuckey Lean of Proverbs* (*English & Foreign*), *Folk Lore, and Superstitions, also Compilations towards Dictionaries of Proverbial Phrases and Words, old and disused*).

See also Alfred Ela, "Longings of the Pregnant, Viewed in Light from the East," *Boston Medical and Surgical Journal*, 183: 576–579; "Obstetrical Superstitions," *Pennsylvania Medical Journal*, 21. 478–480.

[18] I.e., apes with heads resembling those of dogs.

[19] Isidore, *Origines*, 12. 1. 60.

[20] Aristotle, *De Generatione Animalium*, 769 b 14–15.

[21] *Martin Chuzzlewit*, Chapter XLVI.

[22] Cf. Daniel L. and Lucy B. Thomas, *Kentucky Superstitions*, No. 3: "If an expectant mother places her hand upon her body, the child will have a birthmark at the position on its body that she presses." A clipping from a medical column of a newspaper reads as follows: "My sister-in-law is in the first month of pregnancy. While visiting me, I accidentally threw a piece of tomato on her which hit her on the back of her neck. She cried and said that her baby will have a mark." Another popular superstition is as follows: "If an old hare runs across the path of a pregnant woman, her child will have a harelip, unless she can catch up one of her undergarments and tear a slit in it, which will avert the spell." — *Encyclopaedia of Superstitions, Folklore, and the Occult Sciences of the World*, 2. 641. For similiar beliefs see Lean's *Collectanea* (as cited in note 17), 2. 110–111.

satyr, was attributed to the quantity of "unconcocted humour or wind" that was diverted into parts of the face of the foetus.[23] There are many passages in Greek and Latin in which it is stated that a woman gave birth to an animal.[24] Monstrous births are generally associated with war or with other crises, when the feelings of the people were wrought up.

Magical and Other Influences upon the Child

Magic was sometimes resorted to by superstitious women. A concoction called *hermesias* had the singular virtue of ensuring the procreation of issue both beautiful and good. It was a composition made of kernels of pine nuts, pounded with honey, myrrh, saffron and palm wine, to which *theombrotium* and milk were added.[25] For those who wanted babies with black eyes the eating of a shrew-mouse was prescribed.[26] After Philip of Macedon had dreamed that he had put upon his wife's womb a seal with the figure of a lion as a device, one of the seers told him that his wife was pregnant of a son whose nature was to be bold and lion-like.[27]

In the time of Hesiod the ninth day of the first division of the month was regarded as a good day for the begetting or for the birth of a child, both male and female.[28] Women who used too much salt in their food bore children without nails.[29]

[23] Aristotle, *De Generatione Animalium*, 768 b, end. "In the emission of sperm there is a preliminary discharge of air, and the outflow is manifestly caused by a blast of air; for nothing is cast to a distance save by pneumatic pressure." — Aristotle, *De Animalibus Historia*, 586 a 16–18 (D. W. Thompson's translation).

[24] E.g., a lion, Herodotus, 1. 84; an elephant and a snake, Pliny, *Naturalis Historia*, 7. 34; a snake, Isidore, *Origines*, 11. 3. 6; a heifer, *ibid.*, 11. 3. 9. For monstrous births see A. S. Pease. *M. Tulli Ciceronis de Divinatione*, pp. 262–263 (University of Illinois Studies in Language and Literature).

[25] Pliny, 24. 166.

[26] Pliny, 30. 134.

[27] Plutarch, *Alexander*, 2. 3.

[28] *Works and Days*, 811–813.

[29] Aristotle, *De Animalibus Historia*, 585 a 27–29; Antigonus, *Historiarum Mirabilium Collectanea*, 110 (119); Pliny, 7. 42.

TRANSMITTED CHARACTERS

In addition to the superstitions about prenatal influence, there was a very general belief that acquired characters, both physical and mental, were transmitted to children. Thus moles and other birthmarks were said to have appeared in successive generations.[30] Three generations of the Lepidi had a membrane covering the eye, but they were not successive generations.[31]

Antigonus had an anchor upon his thigh. His mother during her sleep dreamed that she had lain with Apollo, and that the god had given her a ring on which was engraved an anchor, with instructions to present it to her son. The child was born with an anchor upon his thigh and his children and grandchildren had a similar mark of their divine origin.[32] The 'Earth-born,' the men sprung from the dragon's teeth sown by Cadmus, had a spear or a star.[33] In the *Thyestes* of Carcinus stars as birthmarks served as a means of recognition.[34]

The Pelopidae were born with one of their shoulders white as a memorial of the experience of the founder of their line, Pelops. His father, Tantalus, had killed him and served him as a banquet for the gods, but Demeter was the only one that partook and she ate a shoulder. On learning what she had done, she caused him to be restored to life, but with the substitution of an ivory shoulder. To this was due the elephantine whiteness of the shoulders of his descendants. Variant stories said that the mark was a spear upon the arm, or a Gorgon, or a trident upon the shoulder-blade.[35–36]

[30] Pliny, 7. 50; Solinus, 1. 78. [31] Pliny, 7. 51; Solinus, 1. 78.
[32] Justinus, 15. 5. 1–9. [33] Aristotle, *Poetics*, 16. 1454 b 21–22.
[34] *Ibid.*, lines 22–23. [35] Scholia on Pindar, *Olympica*, 1. 40 a and c.
[36] There are records of birthmarks upon a number of prominent people. The body of Augustus was generously sprinkled with moles (Suetonius, *Augustus*, 80). "It is said that he had birthmarks scattered over his breast and belly, corresponding in form, order and number with the stars of the Bear in the heavens." — Rolfe's translation. Plutarch, *Fabius Maximus*, 1. 3, tells us that the subject of this biography was called Verrucosus, 'Warty,' because of a wart above his lips. One of the ancestors of Cicero had a dent on the end of his nose which resembled a chick-pea (*cicer*), from which the family got its name. — Plutarch, *Cicero*. 1. 2.

A most remarkable story of control of heredity by man is told by Hippocrates[37] concerning the Macrocephali ('Long-heads'). Since they thought that those members of their tribe with the longest heads (physically, not metaphorically) were the noblest, they molded the heads of infants with their hands and used bandages and other contrivances in order to increase their length. In course of time the head assumed the new shape naturally. He adds, discreetly, that such was not the case in his day, since the Macrocephali had had relations with other men. In supporting his statement he says that children with blue eyes are born of blue-eyed parents; children with bald heads,[38] of bald-headed parents; children with squint-eyes, of squint-eyed parents.

Three chapters farther on[39] Hippocrates states that the women of the Sauromates made a practice of cutting off the right breast of their girls. He makes no suggestion, however, that usage changed nature in this case. One recalls that Chinese babies still are born with normal feet and that millenia of circumcision have not obviated the necessity for its continuance.[40]

There are other stories which place more emphasis on reversion or atavism. Warts, moles and pimples were supposed to appear again after skipping a generation.[41] Aristotle cites the case

[37] *De Aëre, Aquis, et Locis*, 14. Strabo, 11. 11. 8, tells of a tribe, the Signini, with heads so long that their foreheads projected over their chins.

[38] "What evidence we have indicates that a man gets his bald-headedness through his mother from her bald-headed ancestors." — A. E. Wiggam, *The Fruit of the Family Tree*, p. 53.

[39] *De Aëre, Aquis, et Locis*, 17. The fable that the Amazons cut off their right breast is due, perhaps, only to a false etymology.

[40] In view of the experience of the Chinese and the Jews the following clipping, which seems to be based on a magazine article or a book, is amusing:

"But even the Masailand woman's earrings add a bit to scientific knowledge by helping to prove what an adaptable thing is the human body. Generations of wearers of the ponderous rings have developed ear lobes an inch long and twice as thick as our own simply because they had a purpose to serve.

"Same thing is evident among another African tribe where it is the custom to designate a woman's social standing by the number of close fitting brass rings worn around her neck, one on top of the next. The result has been that leaders of the tribal '400' have developed necks two and three inches longer than is normal in proportion to their bodies."

[41] Plutarch, *Moralia*, 563 A.

of a woman who committed adultery with a negro. She had a white daughter, but her grandchild was black.[42] Plutarch [43] tells a more wonderful tale (if indeed it is not an elaboration of Aristotle's story). A woman gave birth to a blackamoor infant. When accused of adultery, she proved that she was descended from an Ethiopian four generations removed.

Plutarch [44] records also that the print of a spear appeared upon the son of a certain Piso, a Nisibian, said to have been a descendant of the Sparti, who were the progeny of the teeth of the dragon sown by Cadmus. He explains that this was the usual mark of that ancient line,[45] but that it had not appeared for many years before, and that with the child it "started up again, as it were, out of the deep, and showed itself the renewed testimonial of the infant's race." [46]

Among the Romans there was a family of Ahenobarbi, 'Bronze-Beards.' One of their ancestors met the Dioscuri as they returned to Rome after helping the Latins win the victory of Lake Regillus. In order to inspire belief in their story of the battle, they stroked his black beard, which immediately turned red.[47] "This sign was perpetuated in his descendants, a great part of whom had red beards." [48]

When a child did not resemble its parents, then the tendency was for it to be like the grandparents or even remote ancestors.[49] This was just as true of mental characteristics which had long been latent. "So many times it happens that the first descendants and eldest races hide and drown the passions and affections of the mind peculiar to the family, which afterward bud forth

[42] *De Animalibus Historia*, 586 a 2–5; *De Generatione Animalium*, 1. 18. 722 a 9 (see Arthur Platt's note *ad loc.* in the Oxford translation); Antigonus, 112 (121). Cf. Pliny, 7. 51; Solinus, 1. 79.

[43] *Moralia*, 563 A.

[44] *Ibid.*

[45] See also Aristotle, *Poetica*, 16. 1454 b 21–22; Dio Chrysostom, *Orationes*, 4. 23; St. Gregory (Nazianzenus), *Letter 38* (*Patrologia Graeca*, 37. 79); *idem*, *Carminum Liber II*, 127–129 (*Patrologia Graeca*, 37. 1515); Julian, *Orationes*, 2. 81 C; Hyginus, *Fabulae*, 72.

[46] From the translation as corrected and revised by W. W. Goodwin, 4. 176.

[47] Plutarch, *Aemilius Paulus*, 25. 2.

[48] Suetonius, *Nero*, 1 (Rolfe's translation).

[49] Aristotle, *De Generatione Animalium*, 768 a 13–22.

again, and display the natural propensity of the succeeding progeny to vice and virtue." [50]

In an effort to prove that acquired characters could be inherited, the ancients appealed to the supposed fact that traces of scars appeared on children at the same places as on the parents. There was the case of a man at Chalcedon who had upon his arm a branded letter which left its impression, although not sharply defined, upon the arm of his child.[51]

Marks, presumably a kind of tattooing, upon the arms of the Daci for the purpose of denoting their origin, are said to have been transmitted to the fourth generation.[52] In the *Problems* [53] of Aristotle the question is asked why it is that letters are found on the fruit of a tree grown from a nut on which letters have been written. Answer is made by citing the case of scars.

The idea that deformities, defects and mutilations are inherited, which the health columns of our newspapers show is still firmly fixed,[54] is doubtless a survival from remote antiquity. The lame and the blind especially were supposed to reproduce their kind.[55] Aristotle [56] notes, however, that most of the children of maimed persons are sound, and Pliny,[57] doubtless under

[50] Plutarch, *Moralia*, 563 B (translation as corrected and revised by W. W. Goodwin, 4. 176).

[51] Aristotle, *op. cit.*, 721 b 30–35. Cf. *De Animalibus Historia*, 585 b 33–36, where, however, he says that a mark on the arm was transmitted to a grandson. Other references to inheritance of scars are Antigonus, 112 (121); Pliny, 7. 50; Solinus, 1. 78.

[52] Pliny, 7. 50: cf. 6. 11; 22. 2; Cicero, *De Officiis*, 2. 25; Ammianus Marcellinus, 31. 2. 14; and perhaps Strabo, 7. 5. 4, for similar instances of marking the body. See *Nature*, 3 (1870). 168, for the belief that tattooing may be seen on the bodies of new-born children of the Sioux Indians.

[53] *Problemata Inedita*, Sectio 3, No. 1 (ed. Didot, 4. 326).

[54] A communication from one anxious correspondent was printed in *The Chicago Tribune* of February 14, 1923: "1. If both parents are minus the right arm, will their children be normal? 2. If both parents are paralyzed in their right arm, will their children be normal?"

I have two clippings in which the question is asked whether a pregnant woman may have her teeth filled. "An expectant mother should not have her teeth filled." — D. L. and L. B. Thomas, *Kentucky Superstitions*, No. 4.

[55] Aristotle, *De Animalibus Historia*, 585 a 27–29; Antigonus, *Mirabilia*, 112.

[56] *Ibid.*, 585 b 35–36; *De Generatione Animalium*, 724 a 3–4.

[57] 7. 50.

his influence, says that cripples are born from normal parents and normal children from crippled parents. I am wondering whether it would be trite to quote in this connection Professor Conklin's *bon mot:* "Wooden legs are not inherited, but wooden heads are."

Greek and Roman parents had the legal right to expose their children, but I have nowhere found in the classical literatures any statement that defectives were destroyed for fear that they would bring more defectives into the world.[58] There were inevitable eugenic benefits from the removal of inferior protoplasm, but they were incidental[59] and were doubtless more than counterbalanced by the exposure of highly endowed infants from good families. The custom of exposing children was perhaps never as prevalent as we are inclined to believe, certainly not for the fifth and fourth centuries before Christ at Athens.[60]

[58] We learn, however, that the ancient Scots practised castration and at times inflicted death for the good of the race. A passage in the first book of Hector Boethius, *De Veterum Scotorum Moribus*, is thus translated by Burton, *Anatomy of Melancholy* (1850 edition), p. 136: "if any were visited with the falling sickness, madness, gout, leprosy, or any such dangerous disease, which was likely to be propagated from the father to the son, he was instantly gelded; a woman kept from all company of men; and if by chance having some such disease, she was found to be with child, she with her brood were buried alive: and this was done for the common good, lest the whole nation should be injured or corrupted."

[59] One of the reasons why the ancients exposed normal children was because they did not want the trouble and expense of rearing them. These considerations would be stronger in the case of defective children. With the individual the good of the race is an abstraction. Personally I believe that the benefits of infanticide have been exaggerated even in A. G. Roper's admirable essay, *Ancient Eugenics*, pp. 5–16.

I have but three references in Latin with regard to the exposure of deformed infants. One child, a mythical case in Livy, 27. 37. 5–7, was drowned because it was a monstrosity. Seneca, *De Ira*, 1. 18, says that monstrosities were regularly drowned. Seneca here advocates the separation of the unfit from the fit for the coldly matter-of-fact reason that they were useless. A law in the Twelve Tables has reference to the conspicuously deformed (*insignis ad deformitatem*), according to Cicero, *De Legibus*, 3. 19. Roper says (p. 12), mistakenly, I believe, that the law "was ordained by the Twelve Tables for a definitely Eugenic motive."

[60] See La Rue Van Hook, "The Exposure of Infants at Athens," Transactions of the American Philological Association, 51. 134–145; H. Bolkestein, "The Exposure of Children at Athens and the 'εγχυτρίστιαι," *Classical Philology*, 17: 222–239.

Drunkenness was likewise supposed to be inherited.[61] Trimalchio, a character in the *Satyricon* of Petronius, says: *Non negabitis me habere Liberum patrem.*[62] The most interesting passage on the subject is to be found in Plato's *Republic:*[63] "Wherefore, also, the drunken man is bad and unsteady in sowing the seed of increase, and is likely to beget offspring who will be unstable and untrustworthy, and cannot be expected to walk straight either in body or mind. Hence during the whole year and all his life long, and especially while he is begetting children, he ought to take care and not intentionally do what is injurious to health, or what involves insolence and wrong; for he cannot help leaving the impression of himself on the souls and bodies of his offspring, and he begets children in every way inferior."[64]

At the time of procreation a temporary or passing attitude of mind of the father was supposed to affect the character of children. Thus Hesiod advises a man not to beget children when he has just returned from an ill-omened funeral, but rather after having engaged in a festival of the gods.[65] Incontinence produced an intemperate and vicious offspring.[66]

Hippocrates held that healthy parts of the body were inherited from healthy parts and unhealthy from unhealthy.[67] Hence he naturally believed that such diseases as dropsy, con-

[61] Plutarch, *Moralia,* 1 D–2 A. Diogenes said to a crack-brained stripling: "Young man, thy father sowed thee when drunk." Philostratus, *Apollonius of Tyana,* 3. 40, tells a story of a man whose sons died the moment they began to drink, having inherited too warm a temperament. When he asked how to save a child recently born from this inherited tendency, he was told to feed the child owls' eggs that had been boiled.

[62] 41. 8. [63] 6. 775 D. [64] Jowett's translation.

[65] *Works and Days,* 735–736. Plutarch, *Moralia,* 562 A, quotes this to refute it.

[66] Clemens, *Recognitiones,* 9. 9 (*Patrologia Graeca,* 1. 1403). It was a deep-seated conviction of the Christian fathers that concupiscence was transmitted from parent to offspring. The feeling is strongly expressed by St. Augustine, *Contra Iulianum Pelagianum,* 5. 14. 51 (Migne, *Patrologia Latina,* 44. 812). According to St. Augustine, Christ inherited his mortal body from his mother, but because of the manner of his birth he was free from the contamination of original sin. —*ibid.,* 5. 15. 54 (Migne, *op. cit.,* 44. 814).

[67] *De Aëre, Aquis, et Locis,* 14.

sumption, gout and epilepsy were hereditary;[68] likewise that persons who were phlegmatic, bilious, phthisical or splenetic had inherited their afflictions.[69]

It was the custom among some of the Greeks at least for children whose parents had died of consumption or dropsy to sit with both their feet soaking in water until the body was burnt. This precaution was taken in order to prevent the disease from becoming hereditary.[70]

An instance of the transmission of a malady suddenly acquired is seen in the case of the Scythians who had plundered a temple at Ascalon, where they had settled. In requital the goddess punished them with a 'female disease,' which was inherited by their descendants.[71] According to Hippocrates,[72] however, the Scythians in general were subject to a certain disease which made them impotent and caused them to live and work like women. This too was popularly ascribed to divine agency, but Hippocrates attributed it to riding horseback so much.

Characters and Gifts that Ran in Families and Tribes

Ancient literature contains many instances of traits or powers or gifts that 'ran in families.' The Corinthian Timoleon lost his sight late in life. There is a tradition that not a few of his family became blind when enfeebled by age.[73] This is the sole example of homochronous heredity that I have found.

The Agrippae had the misfortune to be born feet first. Of this family Marcus Agrippa was almost the only one that enjoyed prosperity and his happiness was far from being unalloyed.

[68] *Praedictiones*, 2. 5 (Littré's edition, 9. 21).

[69] *De Morbo Sacro*, 2. Compare Theophrastus, *Characters*, 19 (12): "The offensive man is one who will go about with a scrofulous or leprous affection, or with his nails overgrown, and say that these are hereditary complaints with him; his father had them; and his grandfather, and it is not easy to be smuggled into *his* family" (Jebb's translation). See also Strabo, 15. 1. 24.

[70] Plutarch, *Moralia*, 558 D–E.

[71] Herodotus, 1. 105. See H. Stein's note *ad loc.* J. L. Myres thinks that the affliction was merely beardlessness. See pp. 138–141 of his lecture, "Herodotus and Anthropology," in *Anthropology and the Classics*, edited by R. R. Marett.

[72] *De Aëre, Aquis, et Locis*, 22.

[73] Plutarch, *Timoleon*, 37. 5.

His descendant Nero is another illustration of what might be expected from such a 'preposterous' birth.[74]

Not far from Rome in the territory of the Falisci there were a few families called Hirpi. At an annual sacrifice on Mount Soracte they were in the habit of walking over fires without being burned. Because of this power they were exempted from military service and other duties of citizens. Our informant tells us that parts of their bodies were endowed with wonderful properties. They were presumably of a curative nature since a comparison is made with the right toe of Pyrrhus, by touching which persons suffering from diseases of the spleen were cured.[75]

There were tribes too that were especially gifted in some respect. The Psylli, a tribe in Africa, had in their bodies a natural poison that was fatal to snakes, by the odor of which they were accustomed to lull them. When a child was born, it was exposed to the fiercest snakes. If the snakes did not flee, it was a sign that the child was not of pure blood and that the mother had committed adultery.[76] The Marsi in Italy had similar power.[77] The Ophiogenes in the Hellespont were accustomed to extract the poison of snakes merely by laying their hands on the victims.[78] Snakes licked one of their members whom Roman consuls threw into a dolium full of snakes.[79] Others who were born on the island of Tentyra in the Nile caused crocodiles to flee merely at the sound of their voice.[80]

Stories similar to these can be found in abundance at the beginning of the seventh book of Pliny's *Natural History* and in the geographical writers. They can be duplicated of course in modern lore. To cite but one instance, "Some people can stop the flow of blood in other people or in animals. The power runs in families, and a man must teach it to a woman, and a woman to a man." [81]

We are told by a scholiast [82] that almost all the Campanians

[74] Pliny, 7. 45–46. [75] *Ibid.*, 7. 19–20.

[76] Pliny, 7. 14; Lucan, 9. 890–911; Aelian, *De Natura Animalium*, 1. 57. [77] Pliny, 7. 15.

[78] *Ibid.*, 7. 13. In 28. 30 their dwelling-place is given as Cyprus.

[79] *Ibid.*, 28. 30. [80] *Ibid.*, 28. 31.

[81] D. L. and L. B. Thomas, *Kentucky Superstitions*, No. 1070.

[82] Comm. Cruq., on Horace, *Satire*, 1. 60–62.

had warts on their temples. This statement seems like an obvious exaggeration and may be due in no small measure to the suggestion of the lines upon which the scholiast was commenting. The baldness of the Myconians became proverbial, so that there was a tendency among some of the Greeks to call bald men 'Myconians.' [83] People of Caunus had a reputation for being splenetic.[84]

A story in Ovid's *Metamorphoses* (2. 235–236) accounts for the blackness of African peoples by saying that the chariot of the sun when driven in its wayward course by Phaëthon approached too near and scorched them.[85]

A refreshingly naïve tale in *Uncle Remus* [86] postulates black as the original color of man. There was a certain pool whose waters changed black people to white. Late comers, however, found the water all but exhausted, and could wet only the palms of their hands and the soles of their feet. That is the reason why only these parts of negroes are white. "Niggers is niggers now, but de time was w'en we 'uz all niggers tergedder." [87]

Entire nations were believed to have acquired and transmitted characters that did not have to do with mere physical appearance. The Romans regarded their warlike nature as a racial inheritance and in tradition at least traced it back to Mars. In endeavoring to allay the fear of the Germans under Ariovistus Caesar says to his soldiers: "Whenever anyone declares that it is not incumbent upon us to wage war, he might as well state that it is not necessary for us to amass wealth, or to rule others, or to be freemen, or to be Romans." [88]

At the time of the siege of Syracuse Athenian supremacy upon the water had long been taken for granted. In a speech to the

[83] Strabo, 10. 5. 9. Cf. Donatus on Terence, *Hecyra*, 440; Pliny, 11. 130.

[84] Pliny, 11. 130.

[85] The blackness of the African is usually explained as due to the gradual action of the sun's heat.

[86] By J. C. Harris, 1908 edition, p. 164.

[87] I have used this and similar material on pages 264–265 of an article called "How and Why: 'Just So' Mythology in Ovid's *Metamorphoses*," *The Classical Journal*, 15. 260–278.

[88] Thucydides, 7. 21. 3.

Syracusans Gylippus tells them that Athenian seamanship was not inherited.[89]

There is another class of characters in which the Greeks and Romans were greatly interested and about which they wrote at length, those due to climate and environment. It may be said that the treatise of Hippocrates *On Air, Waters and Places* is based on the hypothesis that variations in the physical and mental constitution of man are due to his readjustment to the climate and the economic régime of the various countries. The subject of climate and character is, however, too big for discussion here.[90]

ANCIENT THEORIES OF HEREDITY

It was a general belief among the superstitious of antiquity that like affects like. The principle of sympathetic magic would doubtless be carried over to apply to the belief in inheritance of deformities and afflictions. The philosophers and scientists, however, tried to find a more rational explanation.

Democritus held that the semen comes from all parts of the body, but especially from the flesh and muscles.[91] Hippocrates likewise taught that the male semen comes from all parts.[92] He postulated an elaborate system of passages by which it was brought, and says that the cutting of the channel beside the ears, which carried most of the semen, would result in impotence.[93] Semen from weak parts was weak; from strong parts, strong; from healthy parts healthy, from diseased parts diseased.[94] If any part of the parent was deformed, the semen was defective and the child would be similarly crippled. Naturally this theory was used in explaining the inheritance of disease. Herodotus goes so far as to say that the semen of the Ethiopian

[89] Cassius Dio, 38. 40.

[90] For many references see Pease, pp. 234–236, as cited in note 24.

[91] As quoted by Plutarch, *Moralia*, 905 A.

[92] *De Aëre, Aquis, et Locis*, 14; *De Morbis*, 4. 32 (Littré's edition, 7. 542); *De Genitura*, 1; 3.

[93] *De Genitura*, 1–2; *De Aëre, Aquis, et Locis*, 22.

[94] *De Genitura*, 8; *De Aëre, Aquis, et Locis*, 14.

is black,[95] but Aristotle [96] scores him for thinking that everything in a black body must be black. He calls attention to the whiteness of the teeth of the Ethiopian.

Aristotle notes four stock arguments for the belief that semen comes from all parts of the body: (1) that the intensity of the pleasure of intercourse is due to its being felt in all parts of the body; (2) that mutilations are inherited; (3) that children are born like their parents part by part as well as in their entire body; and (4) that there is a semen or seed for each of the parts of the body.[97]

After devoting several pages to a refutation of these ideas,[98] Aristotle thus sums up his own views: [99] "So we must say the opposite of what the ancients said. For whereas *they* said that semen is that which comes *from* all the body, *we* say it is that whose nature is to go *to* all of it. . . . For it is more reasonable to suppose that the last extract of the nutriment which goes to all parts resembles that which is left over from it, just as part of a painter's colour is often left over resembling that which he has used up." [100]

Aristotle [101] likewise takes up the question of monstrous births: "If the movements [102] imparted by the semen are resolved and the material contributed by the mother is not controlled by them, at last there remains the most general substratum, that is to say the animal.[103] Then people say that the child

[95] Herodotus, 3. 101.

[96] *De Generatione*, 736 a 10–13. Strabo, 15. 1. 24, is interesting in this connection.

[97] *Ibid.*, 721 b 13–35. [98] *Ibid.*, 722 a — 725 a 21.

[99] *Ibid.*, 725 a 22–28 (Platt's translation).

[100] For a discussion of Aristotle's views on the subject of inheritance in general see Hans Meyer, "Das Vererbungsproblem bei Aristoteles," *Philologus*, 75. 323–363. See also Brock, "Einige ältere Autoren über die Vererbunger-worbener Eigenschaften," *Biologisches Centralblatt*, 8. 491–499.

[101] *De Generatione*, 769 b 12–22.

[102] "The 'movements' are the movements which impart characteristics to the embryo." — Platt on 768 a 13.

[103] "I.e. if the embryo is not properly formed by the influence which makes it develop into a human being, it will resemble a sort of generalized type of animal, such as the foetus appears to be at an early stage." — Platt's note.

has the head of a ram or a bull, and so on with other animals, as that a calf has the head of a child or a sheep that of an ox. All these monsters result from the causes stated above, but they are none of them the things they are said to be; there is only some similarity, such as may arise even where there is no defect of growth. Hence often jesters compare some one who is not beautiful to a 'goat breathing fire,' or again to a 'ram butting,' and a certain physiognomist reduced all faces to those of two or three animals, and his arguments often prevailed on people." [104] A little while previous to this Aristotle makes the statement that a child who does not resemble his parents is in a certain way a monstrosity.[105]

As already noted, Aristotle had observed that the children of cripples were usually sound. With regard to disease Plutarch knew that it was only the tendency that was inherited and he recommended a régime to keep the weaknesses from manifesting themselves.[106] His words on this point are remarkably sane.

SIMILAR BELIEFS IN LATER AGES

In the text and footnotes of this paper I have quoted many parallels from current superstitions. The ancient beliefs have never died and it is impossible to predict a time when they will have succumbed. A writer in the *Pennsylvania Medical Journal* [107] collects a long list of "Obstetrical Superstitions," and urges physicians to familiarize themselves with such beliefs in order to combat them.

It is only in comparatively recent years that well-informed men have been sure of their ground on many ancient ideas that now seem so grotesque. Robert Burton in *The Anatomy of Melancholy* [108] devotes several pages to the inheritance of parental defects and vices.

The first volume of *Anthropologie der Naturvölker,* which was published in 1860 by Dr. Teodor Waitz, professor of philosophy in the University of Marburg, repeats with blissful assurance

[104] Platt's translation.
[105] 727 b 6–7.
[106] *Moralia,* 561 D–562 A.
[107] 21. 478–480.
[108] Pages 133–136 of the 1850 edition.

many instances of hereditary transmission of new peculiarities. In the translation by J. Frederick Collingwood eleven pages (80–90) are devoted to them. Here we find cases in which scars, crooked fingers and other deformities are transmitted to children. Even artificial cranial shapes were supposed to be inherited.

The following illustrations (p. 83) are given with no suggestion of doubt: "Williamson saw in Carolina, dogs which have been deficient in tails for three or four generations in consequence of one of their ancestors having accidentally lost it. A cow, three years old, which had lost by suppuration her left horn, produced three calves, which instead of the left horn presented only a small protuberance on the skin. Dogs and horses whose tails or ears are clipped, often transmit these deficiencies to their offspring."

As recently as 1870 *Nature* was printing a series of items under the title "Hereditary Deformities." [109] Several of the writers are positive that defects acquired by parents are transmissible, while others suspend judgment.

Darwin's famous doctrine of pangenesis, as set forth in *The Variation of Animals and Plants under Domestication*,[110] is remarkably similar to the theory of Democritus and Hippocrates that semen comes from the entire body.

There is still a persistent and insistent desire to believe in the transmission of our acquisitions. Articles on the subject are still welcome in non-scientific literature.[111] Our stubborn retention of the belief has been ascribed to "a human longing to pass on to our offspring the fruits of our bodily gains and mental accumulations." [112]

[109] Vol. 2, pp. 376, 493–494; vol. 3, pp. 7, 47, 127, 168.

[110] Chapter 27, especially note 42 in the second edition. "Under this point of view I venture to advance the hypothesis of Pangenesis, which implies that every separate part of the whole organisation reproduces itself." — p. 339, chapter 27.

[111] See W. P. Pycraft, "The Transmissibility of Acquired Characters," *The London Illustrated News*, June 16, 1923, p. 1034; T. H. Morgan, "Are Acquired Characters Inherited?", *The Yale Review*, July, 1924, pp. 712–729. It must not be inferred that either of these writers believes in the possibility of such transmission.

[112] Morgan, *op. cit.*, p. 729.

The ancients were consistent in believing that if like begets like and if the virtues of mind and body are inherited, their defects must be. Modern science says: "If we cannot inherit the effects of the training of our parents, we escape at least the inheritance of their misfortunes. A receptive mind may be a better asset for the child than a mind weighted down from birth with the successes and failures of its ancestors." [113]

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[113] *Ibid.*

CAN WE ACHIEVE A UNIVERSAL FORMULA FOR RURAL COMMUNITY BUILDING?

KENYON L. BUTTERFIELD

THERE is a decided trend toward evolving some synthetic units of activity in rural affairs. Presumably this is a phase of social organization, although it may be said in passing that the organization of the individual seems to be an increasingly important factor in education.

We have, as examples of this trend, such developments as the following:

1. A county program for agricultural development. This has grown very largely out of the county work of the coöperative extension service.

2. A number of states have already put on paper state programs for agricultural development, and most states are actually working toward some unified program at least for the service of the college of agriculture to the state.

3. For some years past there has been to an increasing extent advocacy of a national program for the improvement of agriculture and country life.

4. The food-supply problem for a large city or a whole nation is up for discussion in many places, and studies of the method by which cities are provisioned have been under way for some while.

5. Then there is the matter of city and country coöperation, a recognition of the mutuality of interest between the two groups. This is taking two forms. First, that of town and country coöperation, by which the large village or the small city works with the farming people in the area around about for common ends. In the second place, there is what may be called regional, or perhaps better, area planning, where the city of

considerable size becomes the center of a plan of general development, economic, social, and otherwise, in its trade area.

6. There is the country church problem, thought of more and more as a unit.

7. There is the commodity problem by which an effort is made to unify the activities of all parties interested in the production of a commodity, such as potatoes, so that there shall be an elimination of waste, development of efficiency all the way from producer to the consumer.

8. Then there is the local community idea. That is most fruitful of all. It has come to the front rather recently, but since the war has developed to such an extent that it is being utilized all over America, sometimes in small programs, sometimes in larger and more comprehensive programs.

Of all these efforts of integration or unity, the local community idea is the most vital. There seems to be a need of a local unit of social organization. At any rate, the idea is growing remarkably. It has a number of phases. There is the New England town, of ancient origin and still maintained. There is the open country community, where there are few villages beyond possibly small hamlets or crossroads. Then there are the town and country communities already referred to and these seem to be particularly ready for development here in Michigan. The community principle is the key to the best rural progress.

And now we come to the question, "Can rural affairs be internationalized, put on a world basis?" I shall not enter into an argument for this, but rather assume it, although, in passing, I might say that when we think of the significance of rural affairs from the standpoint of total rural population, probably a billion; from the standpoint of the service which farmers render society in the production of food; the importance of the farm population element in the development of democracy; the vital significance of the farmers as stewards of soil fertility — all these things seem at once to give us sufficient warrant for trying to internationalize rural affairs and to give validity to rural integration on a world basis.

There are two possible approaches to this integration. One is on the basis of the world's food-supply. This is important. Then there is the basis of community building or organization as a common denominator in all rural matters. The farm village is dominant in most parts of the world, so that there is already an historic and existing integration. Now does this afford a sufficient basis for common interest and practical measures for rural progress? Food-supply, indeed, is significant, but is a complex and difficult question and does not comprehend the entire rural problem, at least, in its practical development.

The development of the local community does comprehend nearly every aspect of personal and social advance. You must remember that the community idea is quite as applicable to planning for production as it is in distribution or in social life.

Our question comes to this then, "Can there be developed a statement or formula that can be utilized everywhere by all groups whether their main interests are economic, social, educational, or religious, and that can be used both as a basis for progress and as a measure of international sympathy and good will among rural folk?"

Many factors have to be considered in giving objectives to personal and collective efforts on a common basis. Such factors as health, education, adequate family life, adequate recreation, aesthetic and civil improvement, moral idealism. Many would wish to add a distinct religious motivation, and probably, in most parts of the world, the religious element will actually enter in. Nor must we forget the economic basis for all this, and in fact that it would be idle to develop such a formula unless it can be applied in terms of securing a larger productivity and a more efficient system of distribution of soil-grown products.

At least three reasons may be given why the query is pertinent.

First of all, in general, we may ask whether this is not the most practical basis for getting "quality" problems among soil tillers brought to the front. Here in the community is where these people live, where their quality of life is determined, and where their quality of life has its influence.

In the second place, there will be an International Conference on Country Life in Europe this summer [1] and this question is going to be raised, and raised because there must be some common language which the rural leaders of the world can speak. Is not this common language found most fully in all the ideas and ideals which cluster about the development of the local rural community in all lands?

For those who believe in foreign missions, this question raises an issue of vital concern. It is quite possible, indeed, that it may be fruitful in revolutionizing the whole purpose and method of so-called foreign missionary work. All the mission lands are rural, and unless their rural civilization can be Christianized, it can hardly be said that foreign missions are a success. The old basis of foreign mission work is passing. Missionaries themselves, at least the missionary statesmen, are seeking a new basis. Is there anything more comprehensive, anything more practical in the application of Christian principles than the building of the local rural community?

You see that I have been raising questions and purposely so. I have no categorical answers to these questions. I think the proposition is of infinite consequence and I lay it before you in that spirit.

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[1] The summer of 1926.

WHAT IS RURAL SOCIOLOGY?

AUGUSTUS W. HAYES

MY REMARKS relating to the subject assigned to me are to be directed toward outlining and placing the field of endeavor commonly labeled under the term, "rural sociology." I am taking it for granted that a discussion of the appropriateness of this title is not desired or needed at this stage in the development of our thought along these lines. I believe that sociologists generally (although they have not always done so), are now accepting this designation as a highly justifiable one covering uniquely an important field of social life.

The increasing complexity of our social structures (and I here use the term "social" in a broad way), together with an awakened, though in many cases a belated, consciousness on the part of society of its greater and greater need of direction and control, have called to the fore, one after another, special approaches to deal directly and effectively with this multiplicity of human relations.

I look upon rural sociology, therefore, as a most conveniently designated social discipline which has for its specific functions a study and understanding of the social phenomena growing out of rural life affairs; their origins, developments, manifestations and present and future usefulness constitute the field of the rural sociologist. Rural sociology takes its place among our increasing numbers of specialized branches of social science as distinctly as do money and credit, labor problems, public utilities, immigration, social psychiatry, social psychology, and a host of others I might mention. It bears a close and contributory relation to the general field of sociology, because, in the end, rural society is but a part of society at large. By common consent, and perhaps for convenience, general sociology is more frequently considered

the mother sociological science whose domain is that of developing in a broad way theories and principles covering the entire field of all human relationships. Rural sociology deals in specific manner with the social phenomena related to country life and the life immediately affected by country life problems. Illustrations of some of these phenomena are found in problems arising out of rural institutional growth and decadence, rural recreational needs and values, town and country social and economic relationships, rural population movements.

I quite agree with Professor John M. Gillette, when he states that, "We may think of rural sociology as that branch of sociology which systematically studies rural communities to discover their conditions and tendencies and to formulate principles of progress." [1]

Sociology lays much stress upon group activities and relationships in the social body generally; so it is with rural sociology, which seeks, for instance, to develop for rural life, plans for removal of undue social isolation, more effective group action, better intercommunication and understanding with other classes in society, higher social ideals, a breadth of interest in and tolerance of other groups making up our social fabric.

One of the outstanding duties of rural sociology, as I conceive it, is to ward off all tendencies in rural affairs to develop farm folk in narrow, provincial lines, and, at the same time, to assist in developing distinctly rural institutions, preserving and conserving all that is typical, ennobling, and uplifting in rural life. This new rural social science must also break the way towards the development and spread of a true culture in rural communities. With the accomplishment of this one task alone its existence may well be justified. Many of the problems of rural community life today go back to the ideals of culture, or total lack of such ideals, prevailing in country districts. We need in the country (and I am not saying that we do not need them fully as much in the city) more real appreciation of the higher planes of human happiness and welfare, better standards of social

[1] Gillette, J. M., *Rural Sociology*, p. 6. The Macmillan Company, New York, 1922.

values, and both personal and social evaluations reflecting the best in national life.

Higher economic returns alone, important as these are, will not secure these things for us; they have not in the past and there is little reason to believe they can do so in the future. Farm leaders themselves have called for and demanded a proper balancing between social and economic factors, so that with the two the country people may go forward to the successful attainment of better ends for rural welfare.

How truly has it already been stated by Dean A. R. Mann of Cornell University: "One of the first obstacles which confronts the sociologist is to clear the path so that the real end may be distinguished from the means for the accomplishment of that end. The besetting sin of a great deal of our present conduct of life is that we are prone to regard as the ends of all our endeavors those things which are merely means to higher ends. We hear it said that the end for which we are working in agriculture is to make farming more productive and profitable. When we have attained that end, however, we have reached only a way station; the terminal lies beyond, and more prosperous farming becomes the means to enable the farmer to share more largely in the higher enjoyments of civilization. We seek better farming that we may have better farmers; we aspire to greater material resources that we may add to the abundance of human resources." [2]

And to all this I may add that the peculiar function of rural sociology is to point the way to these ultimate ends. They do not evolve of themselves or develop out of a *laissez faire* attitude. They come only through the serious, sober contemplation of the human social problems arising out of the busy workaday world and a marshalling of all forces and agencies to meet the particular needs in an effective and satisfying manner.

The highly illuminating studies of recent years in rural standards of living and in the movements of rural population have shown us quite plainly that economic success alone is not

[2] Phelan, J., *Readings in Rural Sociology*, p. 611. The Macmillan Company, New York, 1920.

solving country life problems. The social horizons have been kept too low, the planes for satisfying human social hunger have been too narrow, and the vision of the possibilities of real life-values growing out of rural residence has been left too long undiscovered.

Rural sociology, therefore, has a fertile research field, and a fertile leadership field, in discovering and in pointing the way to the attainment of life's higher values. Let me assure you that our new rural social science is fairly entering her domain. She has already found a place, with at least a general course in rural social problems, in practically every established department of sociology in the United States; in sectarian and non-sectarian schools, in state universities, and in privately endowed colleges and universities, and in normal schools. Books, pamphlets and bulletins on rural life are on reading circle lists in scores of states and the demand is ever growing and enlarging. In some of our leading agricultural colleges and experiment stations we find the greatest developments taking place. Our own state college at East Lansing is now offering about ten separate courses in rural social life. Many of the agricultural experiment stations throughout the country have one or more special full-time workers conducting research investigations in the social problems of farm life within their respective states. Only last year Congress, in passing the Purnell Act, gave added impetus to this line of work. The United States Department of Agriculture has been maintaining for the past six or eight years a Division of Rural Life Studies, which has made some illuminating investigations, both by its own workers and through assistance given coöperating institutions.

The extension departments of universities and colleges of agriculture are now employing community advisors, community dramatists, and leaders to aid farm people in better developing their organized life.

The day is almost at hand when we can say for rural sociology, as a general field, what has been stated for general sociology; namely, that it embraces certain specific phases of rural social disciplines which demand separate treatment and

study for their fullest development. In response to this interesting growth within the domain of rural sociology, we find certain of our colleges and universities have already established courses of study, designated as follows: rural social psychology, rural institutions, rural populations, rural recreation, town and country relations, rural community organization, and rural welfare work.

I feel that one of the most fundamental approaches to a proper understanding of the field of rural sociology is to be gained through the study of the farm family. It seems to me this important primary institution has not received the proper sociological investigation and interpretation in our haste to get to seemingly larger phases of the field. I dare say the farm family is today our most typical American family. Do we know that it will always remain so? What are the forces operating upon it to undermine or destroy its strength and virility, or to develop and increase its usefulness? Is it not the task of rural sociology, with its fitting technic, to dig deeply into these problems and give us constructive leadership here? We need to know more of the effects of different family patterns, both upon society and upon individuals. Our rural institutions and social and recreational life in the country need a more fundamental insight into the peculiar unity relations characteristic of the farm family. The recognition of woman's essential part in rural social affairs, her never dying hopes of elevating social influences for her family and herself are things demanding greater consideration and knowledge. Out of all this, together with understanding the farm family in relation to its physical environment, grow distinctly interesting and valuable psychological phenomena.

No one will doubt the value of good health, both physical and mental, in relation to social life. In country districts we have distinct questions of this sort to meet and solve.

Dr. L. L. Lumdsen of the United States Public Health Service states that "Rural health work is directly applicable to over 50 million of our population; and because of the increased and increasing facilities for traffic, transportation, and travel, it affects the welfare of our city dwellers."

In educational fields, rural sociology is concerned not with

the technic or administrative problems involved, but with the social aspects better educational agencies will develop for rural districts. In religion, in government, in politics the same attitude is fostered and like ends are sought.

In this rather incomplete survey of the various provinces falling within the field of rural sociology I think of one other awaiting directive action; namely, the development of definite rural life policies. Probably no better illustrations of such need have ever existed than exist today. What are we working for as a people; what place have we given or are trying to give agriculture in our national social fabric; do we fully understand the underlying relations of the social and economic consequences of the various categories certain political and commercial leaders are trying to assign to agriculture? These and a multitude of allied problems confront us. Rural sociology must have a dominant part to play in solving these, because of its relations to ultimate social ends and social values. It must help us give to country people, and to society at large, such an understanding of facts and of principles bearing on the important interrelationship of rural affairs with affairs in general as will assign to agriculture and its participants, the place in society consistent with their true importance and worth. Agriculture, and all the other interests, cannot afford, in the end, to accept anything less, and neither can they long delay bringing to fruition such a policy and consensus of mind.

University of Michigan

A POSSIBLE OCCURRENCE OF THE RICHMOND FORMATION IN THE VICINITY OF CLAYTON, IDAHO

CHARLES W. COOK AND GEORGE M. EHLERS

CLAYTON is situated near the center of Custer County, Idaho, approximately fifty miles northwest of Mackay, the terminus of the Blackfoot division of the Oregon Short Line Railroad. The main stratigraphic features of the area have been described by Umpleby [1] as follows: "The oldest rocks exposed in northwestern Custer County are schists, slates and quartzites of Algonkian age. Unconformably on these rocks in the eastern and locally in the northwestern part of the area lies a great series, at least 9,000 feet thick, of Paleozoic quartzites, slates and dolomitic limestones. These were not further subdivided, although there is some reason for thinking that they range in age from Cambrian to Devonian inclusive." He further states that fossils were not found. The finding of fossils in the Clayton area is thought, therefore, to be of sufficient significance to warrant recording the fact.

Fossils were found at two places in the canyon of Squaw Creek, a tributary of the Salmon River, entering this river from the north at a point about four miles west of Clayton. The fossils suggesting the possible occurrence of the Richmond formation in the area were obtained from a dark gray, finely-crystalline dolomite exposed near the Redbird mine on the east side of Squaw Creek five miles above its mouth. Similar material was found at the Saturday mine on the west side of the canyon near the mouth of Squaw Creek.

All the fossils examined belong to a single species of com-

[1] Umpleby, Joseph B., *U. S. G. S. Bull.*, 539, 1913.

pound coral. The specimens of the coral are composed of cylindrical corallites, usually separated from one another by interspaces of about 1 mm. to 5 mm.; some corallites are in contact and a few others are distant from one another as much as 10 mm. The average diameter of the corallites is about 3.5 mm. The diameter of the smallest one observed is 2.5 mm. and of the largest 4.5 mm. Where they appear at the surface of the weathered dolomite, the corallites are more or less silicified and show very imperfectly the septal arrangement. In a few better preserved corallites, sixteen septa reaching nearly to the center of the corallite were counted; alternating with these are shorter, almost rudimentary septa. The exterior of the corallites is marked by indistinct annular lines of growth and faint longitudinal lines corresponding with the septa within. Below the weathered surface of the rock, the corallites show no internal structure, owing to the fact that they have been removed by solution and the resulting cavities filled with crystalline, yellowish-stained calcite and a small amount of quartz. Such structure as is preserved in the corals suggests very much that of the late Richmond species, *Columnaria* (*Palaeophyllum*) *stokesi* (Edwards and Haime). Better preserved specimens of this coral may show structures proving this tentative identification of the coral to be incorrect.

Although the evidence is not conclusive, the corals are strongly suggestive of the late Richmond age of the beds in which they occur. On lithological grounds, Umpleby correlates the Clayton section [2] with the section near Gilmore,[3] Lemhi County, and assigns the 200–300 feet of massive blue dolomite above the massive quartzite to the Ordovician. In the Gilmore area, he found two groups of fossils concerning which Kirk [4] says they "seem to indicate unquestionably the Richmond age of the beds." In the Mackay area, Umpleby [5] also obtained a few fossils from the dolomitic beds above the massive quartzite, which he quotes Kirk [6] as saying "are certainly Richmond in

[2] *Ibid.*, p. 20.
[3] *U. S. G. S. Bull.*, 528, 1913.
[4] *Ibid.*, p. 33.
[5] *U. S. G. S. Prof. Paper* 97, 1917.
[6] *Ibid.*, p. 25.

age" and "should be correlated with the Fish Haven dolomite of Richardson."

It may be of interest to point out that Ulrich [7] in his paleogeographic map of Richmond time has extended the sea into and beyond the area in which the fossils under discussion were found. If this extension of the sea is based upon fossils from this area, the writers are unaware of the fact and believe that the occurrences just described afford evidence in substantiation of this portion of his map.

No attempt has been made to establish a stratigraphic section for the area in which the fossil corals were found as a considerable amount of faulting has taken place there. Hence, in the absence of more fossil evidence, more detailed knowledge of this faulting than is at hand at present, is necessary before the attempt should be made to establish a stratigraphic section on lithological grounds alone.

University of Michigan

[7] Ulrich, E. O., *Congrès Geologique International, Compte Rendu de la XII^e Session*, p. 665, 1913.

THE GEOLOGY OF LA SAL MOUNTAINS OF UTAH

LAURENCE M. GOULD

CONTENTS

I. Physiography

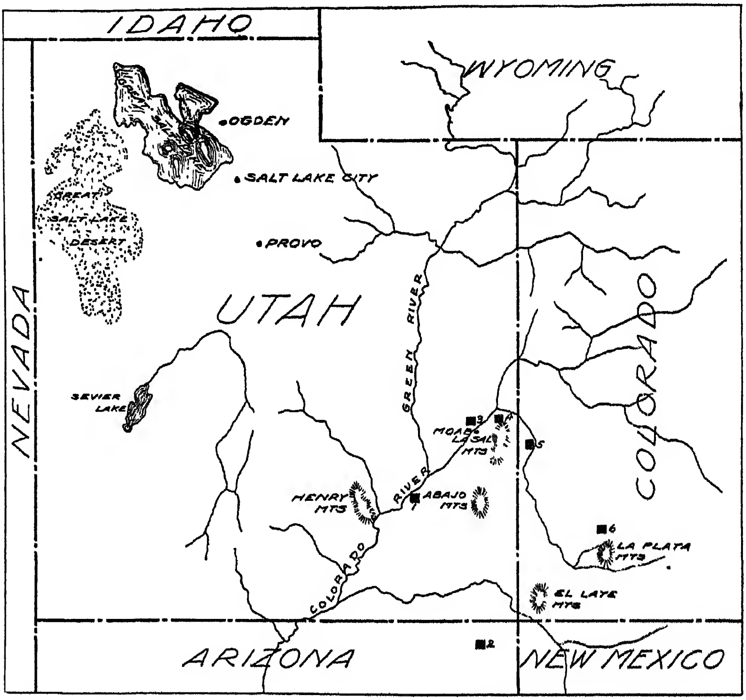
LA SAL MOUNTAINS lie within the great Colorado plateau country so notable for its cliffs and canyon walls which exhibit with unparalleled perfection great cross-sections of the earth's history. The mountain group is nearly bisected by the meridian of 109 degrees and 15 minutes west longitude and lies between 38 degrees and 20 minutes and 38 degrees and 35 minutes north latitude (Map 1). The Colorado–Utah boundary line is distant only seven miles to the east.

One's first impression of this plateau country is deceptive. It seems to be a relatively flat surface possessing no marked features of relief; one needs to travel but a short distance across it, however, to be undeceived. It is found to be dissected by a veritable maze of canyons, most of which are steep-walled and present few favorable crossings. Permanent streams are found in only a few of them. The deceptive character of the topography is due primarily to the fact that there are practically no features, aside from the mountains themselves, which have been caused by uplifts of any consequence. The immense incisive work of running water over a once relatively flat surface

has been the major factor in the development of this peculiarly deceptive relief. The almost total absence of depositional features further accentuates the results of the stream action.

Influence of Structure on the Erosional Processes

In the erosional processes which have been operative, whether due to wind or water, the rock structures have con-



MAP 1. Index map to show location of La Sal Mountains and other laccolithic mountains of neighboring regions and of the areas from which the columnar sections of Figure 1 are copied or derived

trolled to a marked degree. Indeed one might almost say that the present physiographic development is a direct reflection of the structural features of the plateau province. Longitudinal

fractures along the nearly flat-lying anticlines facilitated the establishment of streams until these structures have become valleys separated by mesa-like lands which represent the synclinal areas. Joints and faults in the Navajo sandstone, which covers so much of the surface west of the mountains, have controlled the weathering and erosional processes with the production of rounded and elongated dome-like forms almost equally spaced. Northwest of the mountains, where the Wingate is the cover rock, fractures and joints have caused the formation of great mesas, which with the passage of time have been subdivided into smaller mesas and these in some places into buttes often capped only by small pinnacles (Pl. I, Fig. 1) of what formerly was an extensive overlying rock.

Work of Running Water and Wind

Because of the immense amount of denudation which this region has undergone since Tertiary time, it is not possible to estimate the rate of the various agents operative in this semi-arid climate, or to evaluate with any degree of accuracy their relative importance. It is obvious, however, that running water has played the major rôle. The sparseness of the vegetation has been an important factor in the operation of this process as well as in the work of the wind. The run-off is extremely rapid and correspondingly effective in its erosional effects. In but a few minutes what seems to be a small rain may fill perfectly dry washes with raging torrents which transport enormous amounts of detrital matter. In an almost equally brief time enough water and débris may be added to the Colorado itself from side canyons to change it from a rather shallow stream, sluggish in places with noticeable sand bars, into a muddy turbulent river carrying an immense load. In the various weathering and erosional processes which are contributory factors to the efficiency of this sort of denudation, wind, temperature changes and frost, in the order named, are the most important. The wind is effective in two ways. In the first place it is an important agent of transportation in bringing much sand and other detritus to the streams or canyons where it may be further worked over and carried away.

Again, in the formation of many of the land forms which now stand out in relief, wind action is seen to have been a dominant factor. Mention has already been made of the buttes and mesas in the Castle Valley region, which show in part the effects of wind, but a much more interesting group of such erosion remnants are the so-called "windows." These lie on the west side of Colorado River about twelve miles northwest of Moab. Here is a veritable museum illustrating the varied and fantastic forms that may result from wind-weathering and erosion. Joints together with cross-bedding have so controlled the denudational processes that massive castellated forms, chimneys, caves, bridges and arches of great variety have been developed (Pl. I, Fig. 2). This group of features presents such unusual scenic effects that from this standpoint alone they are deserving of wider recognition, and it is of interest to note that a movement is now on foot to have this unique region set aside as a national monument.

As one proceeds towards the mountains from the west, he is impressed with the changing profiles presented by the various physiographic forms. Whether the route is through Castle Valley (Pl. I, Fig. 1) or makes its way up over the sand flats (Pl. II, Fig. 2) from Moab, the sharp clean-cut erosion forms of semi-arid climates dominate the early part of the trip. As one ascends the first mesas west of the mountains, these give way to softened slopes and to land surfaces partly covered with vegetation, and finally as one climbs the last shelf adjacent to the foot of the mountains he finds himself on rounded forms such as characterize humid climates.

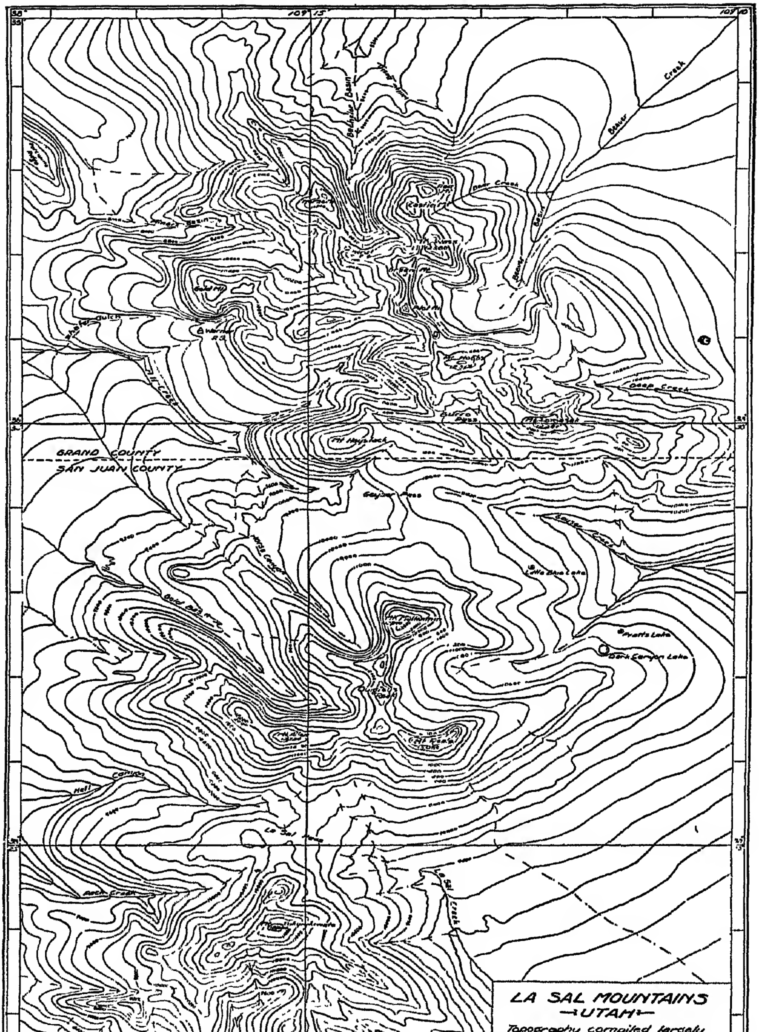
Vegetation is much thicker and the lower slopes of the mountains are densely forested with aspen and spruce. As one finally stands on the mountain tops the contrasted aspect presented by the plateau country on the Colorado side of the mountains as compared with that on the Utah or western side is very striking. To the west, except for the forested slopes of the mountains themselves and the vegetation-covered mesas that stretch a few miles out into the plateau lands, the landscape is largely one of bare rock surfaces. Even from so great a distance all manner of

erosional forms typical of semi-arid climates are easily recognized. The buttes and mesas of the Castle Valley region and the rounded dome-like forms of the Navajo sandstone can be clearly identified. On the east or Colorado side of the mountains the bright-colored canyon walls of bare rock surfaces stand out in sharp contrast against the green of the more or less vegetation-covered lands. Sharp or clean-cut profiles like those of the western side are here much less pronounced. It is evident that on this side of the mountains more humid climatic conditions obtain.

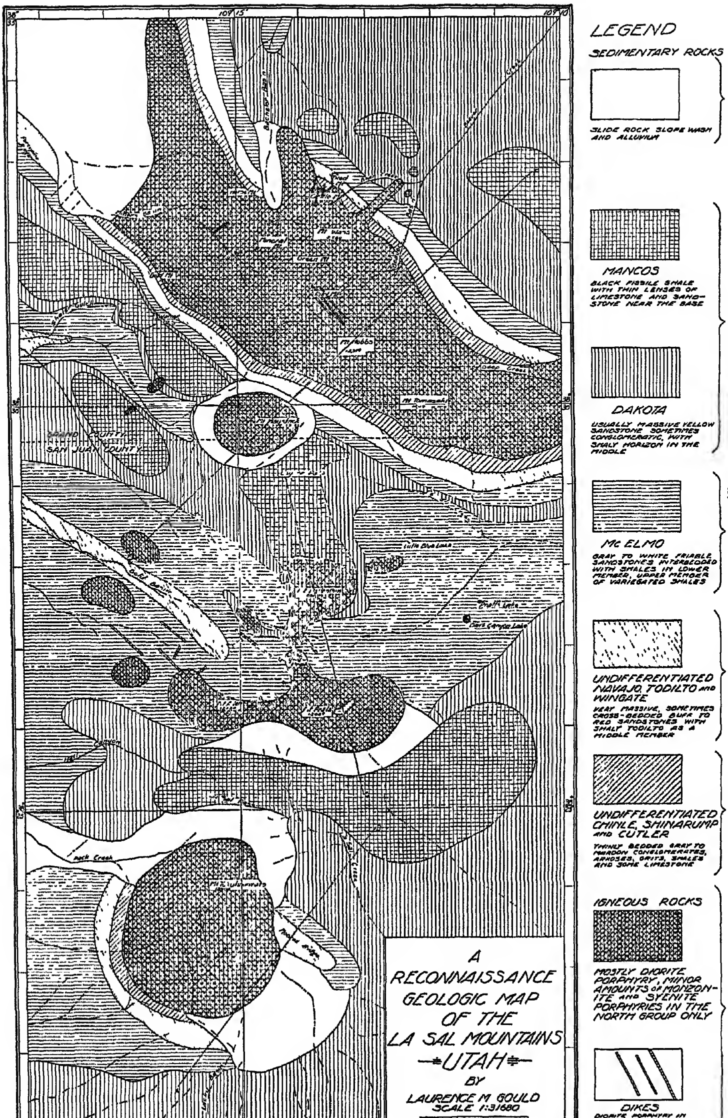
PHYSIOGRAPHIC DEVELOPMENT OF LA SAL MOUNTAINS

The Distribution of the Peaks and the Relief

La Sal Mountains as a whole consist of some twenty major peaks divided into three groups (see Map 2). These groups indicate areas of igneous activity and are separated by sedimentary saddles. Geyser Pass divides the north and central groups and La Sal Pass the central and southern groups. These passes are about a mile and a half wide. Most of the peaks are in the north group, which is greater in extent than the other two groups combined; only one major peak is found in the south and only three in the central groups. The central group, however, is considerably higher than either of the end groups and the three peaks here are the highest mountains in the whole region. The upper slopes of the mountains for 2,000 to 3,000 feet are quite precipitous. On the eastern side the lower slopes flatten out gradually and continue into Colorado at the level of the Dakota sandstone. Westward toward the Colorado River the descent from the mountains is more precipitous. The upturned sediments about the igneous cores flatten out very near the mountains proper, but the farther one goes westward from the mountains the greater is the depth to which erosion has proceeded. As a result, one descends by a series of stratigraphic steps, often with enormous treads, from the Mancos shales of Cretaceous age adjacent to the mountains, to the Carboniferous exposed in Moab Valley near the Colorado River. The summits of the



Map 2. Topographic map of La Sal Mountains



MAP 3. Geologic map of La Sal Mountains

peaks range in height from 11,000 to 13,000 feet. At Moab the Colorado River reaches a level of 4,000 feet. Of this difference in elevation between the mountain tops and the Colorado, fully half is due to the mountain uplift.

Weathering and Erosional Processes

The mountains, including the sedimentary saddles or passes, are so much higher than the surrounding country that the drainage system as a whole is practically radial (see Map 2). The principal streams which drain into the Dolores River are: Beaver Creek, which heads in Beaver Basin of the north group; Rock Creek, which is formed by the junction of Geyser Creek and Deep Creek; and La Sal Creek (Tukuhnikivats Creek of the Hayden Survey map), which heads in La Sal Pass and the south group. The streams which flow directly into the Colorado River are Mill Creek which drains the greater part of the western slopes of the mountains and enters the Colorado by way of Spanish Valley and Castle Creek, which heads in the north group and enters the Colorado through Castle Valley. Though many of the mountain streams are not permanent, those whose courses extend across the surrounding mesas have in many cases cut deep canyons; of these the Mill Creek Canyon (Pl. VI) is the most pronounced.

So far as the surface expression of the north and south groups of the mountains is concerned, the structure has had a profound effect. The shaly or thinly bedded strata adjacent to the igneous centers have eroded more rapidly than either the massive sandstones farther removed or the hard porphyry cores themselves. Hence these two groups present the aspects of gigantic necks surrounded by loosely fitting collars. In some places the mountain streams parallel the neck until an opening across the massive collar is reached. Structural conditions such as those described are lacking in the central group, so that here the higher precipitous mountain slopes merge with the lower slopes with no great breaks and the drainage is quite regularly radial.

Above the vegetation-covered slopes of the mountains the rocks have been so split and broken up by very intensive frost

action that even the peaks and most of the slopes are covered with loose angular blocks sometimes of enormous size.

Glaciation in the Mountains

The effects of the Pleistocene glaciation are still strongly marked in parts of the mountains. This statement applies to the erosional rather than to the depositional features, for the glaciers were very short and except in the central group did not leave deposits which are still very prominent. The heads of the major valleys in the mountains are referred to as 'basins.' The term in this sense usually means a feature much broader than the typical V-shaped valley head formed solely by the erosional work of running water. Most of these so-called basins are cirques. In the north group Miners' Basin, Bachelor Basin, Beaver Basin (Pl. II, Fig. 1) and Deep Creek Basin (Pl. III, Fig. 1) there occur prominent cirques. The glaciers did not extend far enough from any of these cirques to form recognizable U-shaped valleys. In most of them, however, low rounded deposits of morainal character are still preserved. In the central group the glaciers were developed on a larger scale. The head of Horse Canyon, Gold Basin, and the head of Dark Canyon are all well-developed cirques. In Dark Canyon and Gold Basin (Pl. III, Fig. 2), the glaciers have extended far enough from the cirques to form U-shaped valleys, which are still easily identified. Dark Canyon seems to have possessed the largest glacier in the whole mountain area. It not only scoured out the most extensive U-shaped valley, but left morainal deposits of sufficient magnitude to dam up the valley and to form morainal lakes. Dark Canyon Lake is the largest of these. About three fourths of a mile below it lies Pratt's Lake (Pl. IV, Fig. 1), which shows with particular clearness its morainal dam. Little Blue Lake northeast of Mt. Mellenthin is also a morainal dam lake. These three lakes are the only ones that merit the dignity of being so called, but there are numerous other basins, some of which are filled with swamps which owe their existence to glacial deposition.

There is some question whether or not the south group was

glaciated. It is much lower than either of the other two groups and hence may have escaped such action, but Lackey Basin and the basin to the upper right of Pack Creek may be in part the results of glacial erosion.

Rock Glaciers

So-called rock glaciers are found in nearly all the cirques and along some of the valleys. These present a different profile and relief from ordinary talus slides. Rude concentric ridges characterize the lower lobe-shaped fronts which rise rather steeply from the valley floor upon which they appear to be advancing. Capps,[1] who studied similar phenomena in Alaska, believed that such masses were in actual motion because of the formation of interstitial ice. Howe,[2] after studying the same phenomena in the San Juan Mountains, reached the conclusions that the rock glaciers were not in motion and that their present position is due to landslides rather than to any glacier-like motion induced by the formation of ice in the crevices between the rock fragments. The latter theory seems more probable to the author than that of Capps. The best developed rock glacier in all La Sal Mountains is not found in or at the base of a cirque, but at the bottom of a steep valley side (Pl. IV, Fig. 2). The valley side from which the material of this rock glacier came is still so steep that it is difficult to see how it could have reached its present position in any other way than by landslides, as suggested by Howe.

II. The Sedimentary Rocks

No beds older than Permian or possibly Permo-Pennsylvanian are exposed in the immediate vicinity of the mountain uplift. If, however, we consider Spanish or Moab Valley, as it is variously called, as a part of La Sal Mountain province or region, then there is exposed a sedimentary series extending from the Hermosa of Upper Pennsylvanian to the Mancos of Cretaceous. About a mile of strata is included in this series.

[1] Capps, S. R., "Rock Glaciers in Alaska," *Journ. of Geol.*, 18 (1910): 359–375.

[2] Howe, Ernest, *Landslides in the San Juan Mountains, Colorado. Professional Paper, U. S. Geol. Surv.*, No. 67 (1909): 1–58.

Generalized Section of the Rocks Immediately to the West and Northwest of La Sal Mountains

The thicknesses were measured by aneroid

Series		Formation	Thickness (in feet)	Lithological Character
Cretaceous		Mancos	0 to 600	Black fissile shale with thin lenses of limestone and sandstone near base
		Dakota Sandstone	200	Light yellow, sometimes conglomeratic sandstone; sometimes two sandstone members with thin shale between
Jurassic?		McElmo	1000	Grey to white friable sandstones interbedded with shales in lower part; an upper division of variegated shales
Jurassic	La Plata Group	Navajo Sandstone	800	Two massive members of brick-red to white, sometimes cross-bedded sandstone, separated by a thin zone of red shales, occasionally with some limestone; a prominent cliff-maker
		Todilto	0 to 200	Deep red thinly bedded sandstones and shales
Triassic?		Wingate	100 to 200	Massive somewhat cross-bedded deep red sandstone; vertical joints produce a columnar effect; a prominent cliff-maker
Triassic		Chinle		Thinly bedded red to red-blue sandstones and shales
		Shinarump Conglomerate	200	Very thinly bedded greyish-maroon calcareous conglomerates and sandstones
Permian		Cutler	800+	Purple, red, pink and sometimes white conglomerates, sandstones, shales, grits, arkose and earthy limestones

The Pennsylvanian has but a limited exposure, being found only in the bottom of Moab Valley. And here only a small part of the entire formation comes to the surface. As one studies the successively younger formations to the Navajo, he finds that all have an ever increasing area of outcrop. The Navajo sandstone of the Jurassic has the greatest areal distribution and constitutes the chief surface rock in the region between the Colorado River and La Sal Mountains. On the western side of the mountains, formations younger than the Navajo are restricted to the mesas which extend out five to seven miles from the base of the mountains. The youngest rock, the Mancos shale, is preserved only in small patches on the tops of the high mesas and on the saddles between the three groups. East of the mountains erosion has not proceeded as far as on the western side and the Navajo is nowhere exposed, except along canyon walls and where it is upturned about the mountains. The McElmo and, to a much greater extent, the Dakota, cover the surface on this side of the mountains.

The Pennsylvanian and Permo-Pennsylvanian

In the upper (northwestern) end of Moab Valley a thickness of at least 500 feet of grits, sandstones, shales and limestones is exposed along the valley. This series is predominantly sandstone and arenaceous shale, though some of the limestone strata attain a thickness of as much as 40 feet. The limestones are hard blue and blue-grey, especially in the lower part of the exposure. Reddish limestones are found higher up. Not only the limestones of the lower zone, but the sandstones and shales as well, are generally grey. In contrast to this the upper beds are dominantly red. Cross[3] called this series Hermosa. Its division into a lighter-colored zone below and a dominantly red one above is, however, suggestive of a possible separation of the two parts. Recognizing this fact Prommel[4] calls attention to the striking

[3] Cross, Whitman, "Stratigraphic Results of a Reconnaissance in Western Colorado and Eastern Utah," *Journ. of Geol.*, 15 (1907): 669.

[4] Prommel, H. W. C., "Geology and Structure of Portions of Grand and San Juan Counties, Utah," *Bull. Am. Assoc. Petroleum Geologists*, July–August, 1923, p. 388.

exactitude with which the description of the Rico from the type locality by Cross and Ransome [5] fits the upper portion of this Moab Valley series. He therefore recognizes the upper red portion as the Rico of Permo-Pennsylvanian age and the lower grey members as the Hermosa of upper Pennsylvanian.

The Permian

Because of its predominantly red color and sandy character the Rico is difficult to distinguish from the overlying Permian beds. Lithologically it resembles more closely the Permian above than the Hermosa below. These next younger beds, of Permian age, are the Cutler of the San Juan Mountains or the Moenkopi of the Navajo country. The formation is here mainly a series of thinly bedded maroon, "liver-colored," sometimes purple, conglomerates, sandstones, grits, arkoses, shales and minor amounts of limestone. Though the dominant color of the formation is red, there are lighter-colored horizons, especially in the lower portion. These are grey, greenish or pink grits, arkoses and thin sandstones. Occasional blue-grey or reddish earthy limestones occur with these lighter-colored rocks. The grits are generally friable; some effervesce when treated with dilute hydrochloric acid, which indicates a calcareous cement. Not infrequently the grits and conglomerate beds are three or four feet thick. In one locality a grey grit reached a thickness of from 10 to 12 feet. The upper portions of the formation are generally very thinly bedded and easily eroded. Where properly exposed, they produce a sort of bad land topography (Pl. V, Fig. 2).

The Cutler is locally gypsiferous. On either side of Moab to the east of the Colorado, low rounded hills of gypsum and gypsiferous earth are found along the base of the cliffs that form the valley walls. The upper central part of Castle Valley is covered with a light grey to very white porous gypsum. Together with the steep red-maroon valley walls on either side, this occurrence furnishes a notable display of rock color contrasts. The thick-

[5] Cross, Whitman, and Ransome, F. L., *Rico Quadrangle, Colorado. U. S. Geol. Surv. Atlas*, Folio 130, p. 3.

ness of the gypsiferous part of the formation could not be determined. It is apparently very lenticular, but attains great thicknesses at various places.

The base of the Cutler does not outcrop in Castle Valley nor in the adjacent Colorado Canyon. Its maximum exposure does not here exceed 800 feet. In his Cutler–Moenkopi series, Prommel [6] places 1,300 to 1,400 feet of strata.

The Cutler is separated from the overlying beds by a great unconformity. Less than a mile down the Colorado Canyon from the place where Castle Valley enters, the angular character of this break is clearly shown on either side of the river (Pl. V, Fig. 1). In Moab valley this unconformity is apparent on account of a rapid thickening of the beds toward the northwest.

Although the formations here described as Cutler show many features similar to the Moenkopi of the Navajo country, at no place within the entire area studied is there any equivalent of the De Chelly sandstone. Descriptions of the same series of rocks from Paradox Valley [7] and other localities but a few miles east of the mountains fit the exposures in the immediate vicinity of the mountain uplift so well that it seems desirable to retain the term Cutler for the whole series. To be sure the gypsiferous phase of Moab and Castle valleys has no well-defined equivalents in the San Juan Mountains, nor even in the areas nearer the mountains mentioned above, and it might be well to emphasize the fact that the occurrences of gypsum here described as a part of the Cutler must not be confused with the occurrences of gypsum, gypsiferous shales, and the like, in the bottom of Paradox Valley and in similar localities of western Colorado. Coffin [8] points out that the gypsiferous series in the region of Gypsum Valley are separated from the Cutler by a well-recognized uncomformity. But he further states that considerable quantities of gypsum are found in the red shales of the Cutler itself, though at no place, to judge from the descriptions of the

[6] Prommel, H. W. C., *op. cit.*, p. 389.

[7] Coffin, R. C., *Radium, Uranium, and Vanadium Deposits of Southwestern Colorado. Bull. 16, Col. Geol. Surv.*, 1921, p. 47.

[8] Coffin, R. C., *op. cit.*, pp. 42–43.

sections cited, on a scale comparable to the occurrences in the Moab and Castle valleys. Beds of recognized Permian age carrying gypsum have been described from many widely separated localities in the western states. It is so often not a persistent member that its absence or presence in adjoining areas, such as La Sal Mountain region and the neighboring parts of Colorado, can hardly be considered significant enough to prevent the correlation of otherwise similar beds.

The Triassic Formations

Overlying the Cutler is a series of very thinly bedded maroon or greyish-maroon, partly calcareous conglomerates. The presence of light-colored pebbles accounts for the greyish cast of the rock. These beds are the "saurian conglomerate" of Colorado. In his reconnaissance trip through this region Cross [9] noted the occurrence of fragments of bones and teeth of crocodilian or dinosaurian animals in this member. Some two hundred feet above this conglomerate in Castle Valley comes the massive Vermilion Cliff or Wingate sandstone. The rocks in between evidently do not all belong to the conglomerate series at the base. Indeed the upper portion consists of thinly bedded sandstones and arenaceous shales, in their lithological character, resembling much more closely the massive sandstone above than the conglomerate below. Further, this member thickens perceptibly toward the south. These two series of rocks are believed to be the equivalents of the Shinarump conglomerate and the Chinle of southeastern Utah.

The Dolores of the San Juan Mountains and western Colorado seems to be equivalent to this entire series of conglomerates, sandstones and shales, together with the massive rock at the top which is variously known as the Wingate or the Vermilion Cliff sandstone. Gregory [10] includes the Wingate and Todilto together with the Navajo as the equivalents of the La Plata group of the San Juan Mountains, and places the Shinarump conglomerate

[9] Cross, Whitman, p. 652 of paper cited in note 3.

[10] Gregory, H. W., *Geology of the Navajo Country. U. S. Geol. Surv. Prof. Paper*, 93, p. 16.

and the Chinle formations as the approximate equivalents of the Dolores. Cross [11] in his paper on the *Red Beds* suggests that the Dolores of Colorado includes diminished equivalents of the Shinarump group and Vermilion Cliff sandstone of the plateau province. This view, with some exceptions or qualifications in the case of the Shinarump, was further substantiated by him on his reconnaissance [12] through the then Grand River region of Utah just west of La Sal Mountains. Furthermore the Dolores of western Colorado, only a few miles to the east of La Sals, as described by Coffin,[13] clearly includes the massive member (Vermilion Cliff or Wingate), at the top, together with the formations below, which have been called in this paper the Shinarump conglomerate and the Chinle. Coffin, therefore, considers this massive member as the top of the Triassic. Gregory [14] places the Jurassic-Triassic contact, with a question mark, between the Chinle and the Wingate. Mehl's [15] paleontological studies in the vicinity of Ft. Wingate, New Mexico, would, apparently, place this massive sandstone member in the Triassic, thus raising the Jurassic-Triassic contact to the top of the Wingate; in other words the top of Coffin's Dolores as described from areas in Colorado a few miles to the east of La Sal Mountains.

Regardless, however, of the more exact delimitation of the ages and correlation of these various formations, the more detailed and definitive nomenclature of apparently equivalent strata in southeastern Utah seems more applicable and more desirable than the retention of the name Dolores for so great a thickness of beds that lend themselves rather easily to further subdivision.

In Plate V, Figure 2, the lower bench represents the probable lower level of the Shinarump conglomerate. Below lies the

[11] Cross, Whitman, and Howe, Ernest, *Red Beds of Southwestern Colorado and Their Correlation. Bull. Geol. Soc. Am.*, XVI (1905): 496.

[12] Cross, Whitman, p. 650 of paper cited in note 3.

[13] Coffin, R. C., *op. cit.*, pp. 47–51.

[14] Gregory, H. E., *op. cit.*, p. 17.

[15] Mehl, M. G., Toepelmann, W. C., Schwarts, C. M., *New or Little Known Reptiles from the Triassic of Arizona and New Mexico with Notes on the Fossil Bearing Horizons near Wingate, New Mexico. Bull. Univ. of Okla., New Series*, No. 103, Univ. Series No. 5, March, 1916, pp. 29–32.

Cutler and above, the Chinle, capped by the Wingate. A comparison of this plate with Plate VII, Fig. 1, of *Professional Paper 132*, which illustrates Castle Butte near the mouth of Red Canyon in the San Juan Canyon region, suggests similarities or relationships between the formations indicated too evident to need comment.

The Wingate is a massive somewhat cross-bedded, red-brown rather than vermilion sandstone. In Castle Valley and the general region to the northwest of La Sals it is peculiarly important as a capping for buttes and mesas along which it characteristically outcrops in sharp cliffs. Remarkably well developed vertical joints give the cliffs a columnar effect and frequently cause them to weather into spines or castle rocks (Pl. I, Fig. 1, and Pl. V, Fig. 2).

The Jurassic Formations

Above the Wingate is a series of thinly bedded sandstones and arenaceous shales so like the massive cross-bedded rock below that it might almost be regarded as a shaly phase of the Wingate itself. This member is, however, persistent, sometimes attaining a thickness of nearly two hundred feet. It may, therefore, be considered a separate formation from the Wingate below, and on account of its position between the easily recognized Wingate below and the equally evident Navajo above may safely be designated as the Todilto, which occupies the same stratigraphic position in southeastern Utah.

Of all the formations that have affected the topographic expression of the plateau country to the west and to the south of La Sal Mountains none has played so important a rôle as the Navajo sandstone (the La Plata of the San Juan Mountain region). Most of the fantastic forms that give so much charm to this region are carved from the massive Navajo (Pl. I, Fig. 2).

In many of the places studied, if the major part of the formation is still preserved, it is recognizable in its tripartite divisions, a lower and an upper massive series separated by a thin zone essentially of red shales with now and then some limestone. The lower part consists of massive brick-red to buff sandstones which

in places attain a thickness of four hundred feet. Bedding planes are notably absent. Not infrequently thicknesses of one hundred feet or more in which no indications of bedding planes may be found are exposed along the canyon walls. Particularly good exposures of this member are found along the canyon walls of Mill Creek. These walls are so blackened in places that they seem to have been painted. This effect is produced by a thin rind of desert varnish.

The upper member of the Navajo is a fine even-grained massive sandstone, frequently strongly cross-bedded. It is yellow-brown to orange for the greater part, becoming pink and lighter toward the top. In places the top portion of fifty to one hundred feet is practically white. It is this member of the Navajo that is locally so characteristically weathered into caves, alcoves, arches and numerous other fantastic forms. Small pockets also are common and frequently give to the rock a roughened or pitted surface.

Its massive character makes the Navajo everywhere a cliff-maker, but not with the sort of expression displayed by the Wingate. The Navajo is generally friable, so that particularly where there is no overlying formation its steep walls terminate in rounded forms rather than in sharply angular forms exhibited by the Wingate.

On the so-called sand-flat between the Colorado and the mesas at the foot of the mountains, the Navajo is the chief surface rock (Pl. II, Fig. 2). Its occasional complex cross-bedding, together with its massive character and easy erodibility, have here produced a maze of erosion forms of unusual beauty. In many parts of the region excessive weathering and erosion along the joints have produced the elongated dome-like forms that from a distance so largely dominate the landscape. After the torrential desert rains, these rocks glisten in the sun; they are difficult to cross, hence the local name of "slick rock." These rounded forms are easily recognized from the peaks of La Sals. Because of their frequent and regular occurrence Peale,[16] who

[16] Peale, A. C., *U. S. Geol. and Geog. Surv. of the Territories. 10th Annual Rept. for 1875*, 1877, p. 62.

saw them from the mountains, thought they might be "sheep backs" of glacial erosion. Closer observation by Dr. Peale would no doubt have demonstrated their real origin.

The Jurassic (?) and Cretaceous Formations

The formations above the Navajo, i.e. the McElmo, the Dakota and the Mancos, constitute the fairly gentle vegetation-covered slopes from the mesa rims on the west to the foot of the mountains. Furthermore all three formations are generally easily eroded, so that their intimate relationships are rather obscure. Neither the McElmo-Dakota nor the Dakota-Mancos contacts were definitely located. On the basis of observations with an aneroid the thickness of the McElmo was estimated to be about 1,000 feet, the Dakota 200 feet, and the Mancos shale from 0 to 600 feet.

In a general way the McElmo may be divided into two parts, a lower which consists of sandstones separated by arenaceous shales, and an upper which is predominantly shales. A dense fine-grained reddish sandstone showing vertical jointing similar to the Wingate constitutes part of the mesa rim rock (Pl. VI). Though this member is quite unlike the recognized McElmo sandstone ledges above, it is believed to be here the basal member. In places the Navajo is directly overlaid by a shaly zone containing limestones and chert. But the dense red rim rock seems not to be separated from the Navajo by a well-defined shaly zone.

The other sandstone members of the McElmo are light grey to white. They are loosely cemented, calcareous material often constituting the binding material, and are therefore easily eroded. Occasionally a thin indurated surface gives the rock a pinkish or even darker tinge and makes it also much more resistive to erosion. This lower sandstone part of the McElmo is also characterized by beds of hard blue limestone and chert. On Wilson Mesa the early settlers burned this blue limestone to make lime. Fragments of chert are scattered over the surface in many places, but no beds greater than a few inches in thickness were found. Prospectors bring reports of a great bed of

"chalcedony quartz" almost a hundred feet thick near the south group of La Sals. There was no opportunity to verify this story.

Pieces of silicified wood are not uncommon on the lower parts of the mesas, and fossil bones, which are probably saurian, were noted below Boren Mesa.

The upper part of the McElmo is one of the most vivid and individual horizons about the mountains. A great series of so-called "variegated shales" forms this portion of the formation. Green, blue, red, lavender and purple (with the lavender and purple predominating), together with grey, constitute the base from which the curiously mottled colors of these beds are produced. Varying grades of purity from very arenaceous shales to those which become plastic and slump when wet are represented in these shales. Exposures from slumping along the green vegetation-covered slopes present color displays that are fairly dazzling. When hammered these shales break into small angular fragments, but do not show any tendency toward fissility.

In contrast to the reddish rocks below, which dominate the landscape to the west of the mesas, the Dakota sandstone is light yellow to buff. The yellowish color is due to limonite which is sometimes so distributed in small patches that the freshly fractured surface presents a "freckled" aspect. Generally the Dakota is friable, but in places is indurated and takes on a pinkish coloration.

The lower part of the formation is conglomerate. The small gravel-sized pebbles of quartz, quartzite and chert, which constitute the conglomerate, are not distributed as definite beds but occur as lenses, which suggests a fluviatile origin.

East of the mountains from Geyser Pass the Dakota is easily recognized in its triple division, a lower and an upper massive zone separated by a shaly zone. The shale is carbonaceous and occasionally carries low-grade coal. There is such an occurrence east of Geyser Pass, which in the earlier prospecting days in the mountains was mined by the prospectors for use in their forges.

In places the Dakota is not easily recognizable, for at times

it shows a surprisingly rapid transition from the characteristic occurrence noted above to more thinly bedded strata.

It is because of the extreme facility with which the formations above and below are eroded, and not because of inherent qualities of resistance to erosion, that the Dakota is often a singularly conspicuous formation near the mountains. It stretches away from the eastern foot of the mountains to constitute the main cover rock for much of the eastern edge of Utah and of western Colorado. When upturned about the eruptive centers of La Sals, it frequently forms particularly striking hogbacks (Pl. VIII, Fig. 1).

A few feet above easily recognized Dakota beds below Bald Mesa there was found an exposure of slate-colored to black shale. Thin lenses of blue limestone and some sandstone were found at this horizon. Numerous fossils were collected of which the following species have been identified: *Gryphaea newberryi; Inoceramus dimidius; Baculites gracilis; Scaphites warreni.* This is apparently the Mancos shale. Exposures higher up along the mesa show it to be predominantly a drab to black fissile papery shale. It erodes easily and when wet becomes very plastic. Its surface expression is, therefore, frequently a bad-land sort of topography.

Nowhere about the mountains does the Mancos exist in its full development. It is preserved in small patches northeast of Beaver Basin, on both La Sal and Geyser passes, and caps Boren and Bald Mesas. It attains its greatest thickness at the last named locality.

Pleistocene, Quaternary and Recent Deposits

As a result of the glaciation of the higher mountain valleys during the Pleistocene age some glacial deposits were formed. Most of the glaciers were short, so that the only deposits now recognizable are a few short moraines. Such deposits are found in the various basins of the north and central groups. The best preserved forms are those in the vicinity of Dark Canyon Lake and Pratt's Lake (Pl. IV, Fig. 1), which lie along the flat eastern slopes of the central group.

In many places the lower slopes of the steeper mountains are

covered by great accumulations of slide rock, sometimes in quantities so great that they completely obscure the structural relationships with the surrounding regions.

Varying amounts of slope wash and alluvium are found about all three groups. The heads of the valleys, or the basins so called, are frequently filled with immense thicknesses of such materials. The deposits consist of both fine and coarse clastic materials showing little or no tendency toward assortment. The contained pebbles are subangular, which indicates transportation over but short distances. The upper parts of Castle Valley and Miners' Basin are covered with at least 200 feet, and perhaps much more, of such detritus. Recent gullying in other basins of the north group, but particularly in those about the south group, namely Pack Creek, Pole Canyon, and Lackey Basin, demonstrates the existence of equally great thicknesses of alluvium and slope wash in these basins.

Projecting out into Castle Valley toward the northwest as a spur from the lowest exposed igneous part of the north group is a conglomerate ridge which divides the upper part of the valley into two parts. It consists largely of subangular pebbles of porphyry so loosely cemented together that the rock crumbles easily under a blow from the hammer.

Figure 1 illustrates the relationship which the sediments of La Sal Mountain region bear to those of adjacent parts of Utah and neighboring portions of Colorado and Arizona. The geographic locations of the columnar sections shown in this figure are indicated on the map (Map 1). The sections are compiled from the following sources:

1. *Rock Formations in the Colorado Plateau of Southeastern Utah, and Northern Arizona*, by C. R. Longwell, H. D. Miser, R. C. Moore, Kirk Bryan and Sidney Paige. *U. S. Geological Survey, Professional Paper*, No. 132 A, 1923, Plate II, Section 11.
2. *The Geology of the Navajo Country*, by H. E. Gregory. *U. S. Geological Survey, Professional Paper*, No. 93, 1917.
3. *Geology and Structure of Portions of Grand and San Juan Counties*, Utah, by H. W. C. Prommel. *Bulletin of the American Association of Petroleum Geologists*. Vol. VII, No. 4, July–August, 1923, Plate III. It will be noted that the names of the formations for this section follow the

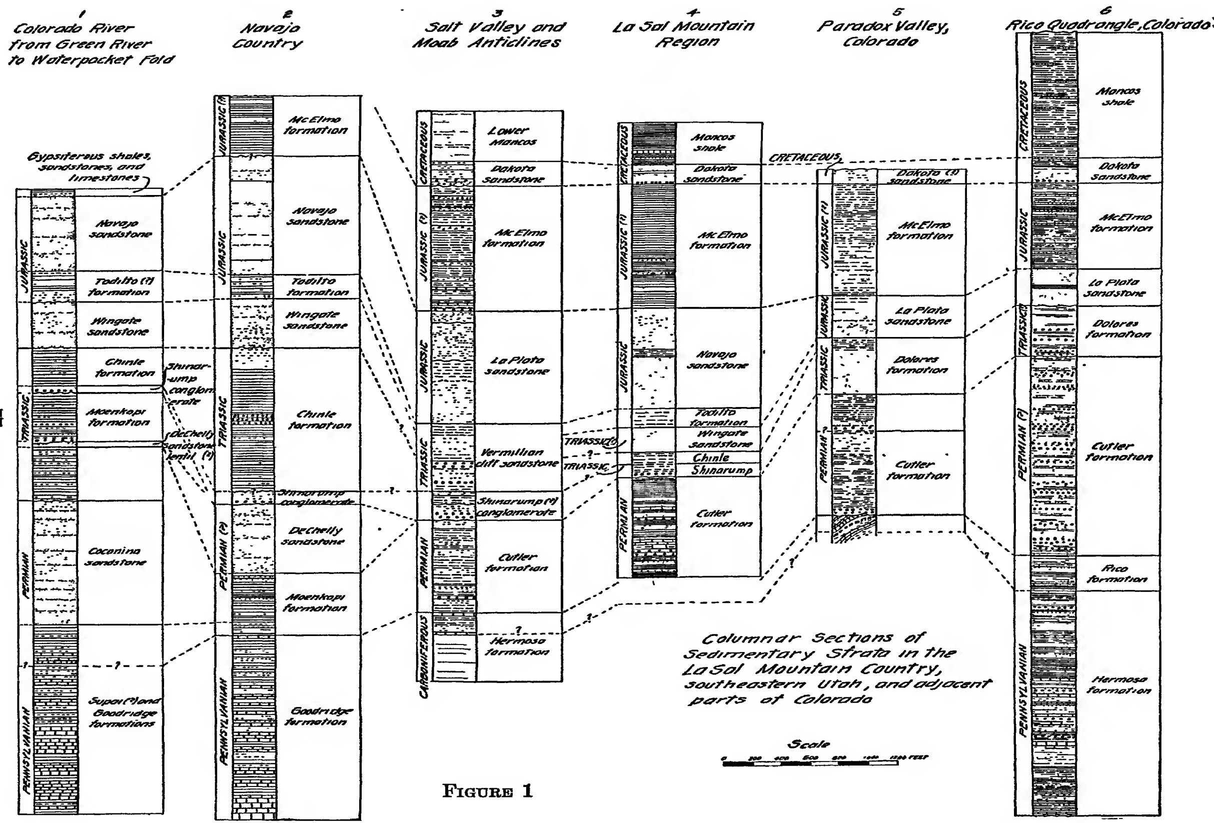

1
Colorado River from Green River to Waterpocket Fold
2
Navajo Country
3
Salt Valley and Moab Anticlines
4
La Sal Mountain Region
5
Paradox Valley, Colorado
6
Rico Quadrangle, Colorado
Gypsiferous shales, sandstones, and limestones
Navajo sandstone
Todilto (?) formation
Wingate sandstone
Chinle formation
Shinar-ump conglom-erate
Moenkopi formation
DeChelly sandstone lentil (?)
Coconino sandstone
Supai (?) and Goodridge formations
JURASSIC
TRIASSIC
PERMIAN
PENNSYLVANIAN
McElmo formation
Navajo sandstone
Todilto formation
Wingate sandstone
Chinle formation
Shinarump conglomerate
DeChelly sandstone
Moenkopi formation
Goodridge formation
JURASSIC (?)
JURASSIC
TRIASSIC
PERMIAN (?)
PENNSYLVANIAN
Lower Mancos
Dakota sandstone
McElmo formation
La Plata sandstone
Vermillion cliff sandstone
Shinarump (?) conglomerate
Cutler formation
Hermosa formation
CRETACEOUS
JURASSIC (?)
JURASSIC
TRIASSIC
PERMIAN
CARBONIFEROUS
Mancos shale
Dakota sandstone
McElmo formation
Navajo sandstone
Todilto formation
Wingate sandstone
Chinle
Shinarump
Cutler formation
CRETACEOUS
JURASSIC (?)
JURASSIC
TRIASSIC (?)
TRIASSIC
PERMIAN
CRETACEOUS
Dakota (?) sandstone
McElmo formation
La Plata sandstone
Dolores formation
Cutler formation
JURASSIC (?)
JURASSIC
TRIASSIC
PERMIAN
Mancos shale
Dakota sandstone
McElmo formation
La Plata sandstone
Dolores formation
Cutler formation
Rico formation
Hermosa formation
CRETACEOUS
JURASSIC
TRIASSIC
PERMIAN (?)
PENNSYLVANIAN
Columnar Sections of Sedimentary Strata in the La Sal Mountain Country, southeastern Utah, and adjacent parts of Colorado
Scale

Figure 1

older nomenclature of the plateau country. In the text, however, Prommel correlates the Permian, Triassic and Jurassic formations with those of southeastern Utah and adopts almost entirely the nomenclature of the Navajo country.

4. Generalized section of the rocks exposed in Castle Valley and along the canyon of the Colorado, north and west of La Sal Mountains, as studied by the author.
5. *Radium, Uranium and Vanadium Deposits of Southwestern Colorado,* by R. C. Coffin. *Bulletin 16, Colorado Geological Survey,* 1921, Plate LV, page 31.
6. *The Rico Quadrangle, Colorado,* by Whitman Cross and F. L. Ransome. *U. S. Geological Survey Atlas,* Folio 130. Generalized Section of Strata in the Rico Quadrangle, by Whitman Cross and Arthur C. Spencer.

III. The Igneous Rocks

Evidence of igneous activity in the mountains is preserved principally as the cores of the three separate groups and as the igneous butte, Little Round Mountains, which lies out in Castle Valley about five miles northwest of the northern group. The latter occurrence is about two miles beyond the border of the area covered by the geological map (Map 3). In addition to these major igneous features a few radial dikes are found in connection with the central group; two small flows or former sheets are known, one as a cap for the lower end of the ridge north of Gold Basin and the other a mile west by northwest of Mt. Haystack. This last occurrence is cut into two parts by the canyon of Mill Creek. Dikes on either end of this bisected mass probably represent the conduits from which the magma came. Finally there is in the north group a number of strongly alkalic dikes which indicate a period of activity subsequent to that of the main intrusion. These dikes are injected into a more alkalic phase of the main intrusive than is elsewhere found. In some places they cut into the surrounding upturned sediments.

All the rocks have a porphyritic texture and in those from the main intrusive mass they are universally characterized by recognizable phenocrysts of feldspar. All the rocks belong to the hypabyssal members of those igneous rocks which are distinguished by the kind of feldspar that predominates. Their

relationships to their plutonic and extrusive equivalents may be indicated thus:

PLUTONIC	HYPABYSSAL	EXTRUSIVE
syenite	syenite porphyry	trachyte
monzonite	monzonite porphyry	latite
diorite	diorite porphyry	andesite

Iddings[17] delimits the three plutonic groups on the basis of the predominating feldspar as follows: 1. Syenites, in which alkali feldspars exceed lime-soda feldspars by more than 5 to 3; 2. Monzonites, in which the alkali feldspars and the lime-soda feldspars vary within the proportions 5 to 3 and 3 to 5; 3. Diorites, in which the lime-soda feldspars exceed the alkali feldspars by more than 5 to 3.

In the determinations of the names to be applied to the rocks of La Sal Mountains, these proportions of the feldspars have been followed as carefully as possible. In fifty thin sections examined, representatives from all three of the hypabyssal groups were recognized. Most of the rocks of the major intrusion are characterized by phenocrysts of plagioclase and very few or none of orthoclase. They are very evidently diorite porphyries. The monzonite and diorite facies are localized, as will appear later.

Occurrence of the Various Types

The southern and central groups, including the radial dikes, Little Round Mountain, the dikes and flow west of Mt. Haystack and most of the north group of the mountains are composed of diorite porphyries.

Only in the northern group is there much evidence of magmatic differentiation. Mineral Mountain represents an area constituted of a particularly clear type of syenite porphyry. As one proceeds from this apparent center of the alkalic phase of the intrusion, there is a gradual decrease in the alkalic feldspars. Green Mountain is very clearly a monzonite porphyry. Sections examined from other adjacent localities demonstrate that parts, at least, of Mts. Waas, Castle and Hobbs are also of monzonite

[17] Iddings, J. P., *Igneous Rocks*, II: 150.

porphyry. The megascopic recognition of most of the monzonite porphyries was of course not possible and the number of slides studied was insufficient to enable one to delimit more exactly this phase of the intrusion.

The small igneous cap on the lower end of the ridge north of Gold Basin is a syenite porphyry differing essentially from that of Mineral Mountain only in texture.

Reference has been made to the fact that associated with the more alkalic phase, just noted, are a number of dikes. These dikes are found principally in two areas; one in Beaver Basin where there are three dikes which have an average strike of N. 40° W.; the other in Bachelor Basin, chiefly in association with Castle Mountain. The dikes in the latter locality have an average strike of N. 15° E. All these dikes are short and most of them were but a few feet in thickness. They represent various facies of syenite porphyries, differing in all cases from the more widely distributed Mineral Mountain and Gold Basin occurrences.

A very different type of rock is that represented by great slides about one half-mile west of the former town of Basin, in Miners' Basin. Though a definite outcrop could not be found, this rock is so different in appearance from the adjacent diorite porphyry that it is believed to be a dike rock. It is a rhyolite porphyry.

THE PETROGRAPHY OF THE INTRUSIONS

Diorite Porphyry

Megascopic appearance. — At first glance the diorite porphyry is seen to be a dense light-grey to white rock with black specks irregularly scattered through it. Closer examination shows that the black specks are phenocrysts of hornblende (many of them acicular in development) which, together with numerous light-colored tabular phenocrysts of feldspar, are imbedded in a light-grey aphanitic ground-mass. Light green phenocrysts of pyroxene are found, but are everywhere much less numerous than the hornblende. Phenocrysts of quartz are only occasionally found. Hornblendic inclusions sometimes measuring as much as four or five inches in length were noted from a few localities.

In some places these grade into the surrounding mass. Careful examination shows that these inclusions consist of the same kind of materials as the main porphyry mass, but are developed on a different scale. Emery[18] describes hornblendic inclusions from the diorite porphyries of Carrizo Mountain which appear to be identical with these noted in La Sal Mountains.

Microscopic description. — Many broad tabular idiomorphic phenocrysts of plagioclase, usually with Albite twinning and often with Carlsbad twins as well, dominate the microscopic appearance of the rock. Most of the plagioclase is oligoclase, andesine, or gradations between the two; more alkalic or more calcic varieties being rare. Zonary banding is common; in one specimen fourteen distinct bands could be noted.

Orthoclase phenocrysts are sparingly distributed or even entirely lacking in the diorite porphyries and when present are always found in smaller crystals than the plagioclases. Most of it shows an elongated rather than a broadly tabular development. Carlsbad twins are common.

Hornblende of the common green pleochroic variety is the characteristic ferro-magnesian mineral. In a few slides there is a little brown hornblende, and in others some bluish-green varieties are noted. Idiomorphic outlines and acicular crystals, many of them with imperfect terminal faces, are common (Pl. VII, Fig. 1). Twinning is frequently noted in the elongated forms. In some places the hornblende is in intimate association with magnetite; in others it encloses magnetite crystals, and again it may be almost completely filled with tiny grains of magnetite, or surrounded by black magnetite borders.

Pyroxene is present in many of the specimens, though usually in amounts subordinate to the amphibole. It commonly shows an idiomorphic development and is frequently twinned. It is usually a pale green to colorless augite (Pl. VII, Fig. 2), though a few varieties from diposide to aegerine were found. Of these aegerine augite is next in importance to the augite.

In four or five slides small amounts of brown strongly pleo-

[18] Emery, W. B. "The Igneous Geology of Carrizo Mountain," *Am. Journ. of Science*, XLII (1916): 356–357.

chroic biotite were found. Even in the same rocks, however, the amphibole was far in excess of the mica.

Although quartz is a characteristic associate of the feldspar in the ground-mass, it is not common as a phenocryst. In only two or three specimens was it present in sufficient amounts to enable one to designate the rock a quartz-diorite-porphyry.

The most characteristic of the accessory minerals is magnetite, which in many specimens is present in two generations. Though not present in amounts so large, titanite is almost as widespread as magnetite. It is developed in long slender crystals which frequently show twinning. Apatite occurs in all the rocks, usually as tiny needles. Zircon, always as tiny grains, is very sparingly distributed in them.

The ground-mass is microcrystalline and consists almost entirely of allotriomorphic quartz and feldspar, usually orthoclase. Considerable variations in the texture of the ground-mass were noted, some specimens approaching on the one hand a coarsely micro-granular texture akin to their plutonic relatives, while others have a very finely holocrystalline ground-mass typically andesitic or trachytic. Fluxion structure was rarely found in the microscopic sections.

In some specimens the rocks were so badly altered that in thin section they presented a dusty or dirty appearance, often making their exact identification questionable. The feldspars were commonly found altering to sericite and to a lesser extent to calcite. Secondary calcite was widely developed in some specimens. In at least two slides the ferro-magnesian minerals were entirely lacking, but epidote was present in considerable quantities. It is sometimes the colorless variety, but more often the greenish pistacite with brilliantly speckled interference colors. In a few slides leucoxene was found. Small amounts of a fibrous material which may be the fibrous amphibole, uralite, were found in two or three slides.

Monzonite Porphyry

Megascopic appearance. — To the naked eye the monzonite facies present no essential differences from the diorite porphyries.

In some places, as on Green Mountain, phenocrysts of orthoclase can be distinguished. Though hornblende is present, pyroxene is usually the dominant ferro-magnesian constituent.

Microscopic description. — Phenocrysts of orthoclase and plagioclase in relatively even amounts characterize these rocks. Both occur in well-developed tabular crystals with idiomorphic outlines. Carlsbad twinning is common in both and of course in the plagioclase, which is most often oligoclase and albite-oligoclase, albite twinning is common. In a few specimens perthite is almost well enough developed to be called a phenocryst. It is commonly found, however, only in the ground-mass.

Both pyroxene and hornblende of the green pleochroic variety are found. The pyroxene is commonly aegerine augite and is often twinned. The same accessory minerals that characterized the diorite porphyries occur also in these rocks.

Considerable variation is exhibited in the ground-mass of the specimens referred to this type of rock. Some are micro-granular and consist of about equal amounts of quartz and feldspar. Others, as those from Green Mountain and near by in Bachelor Basin, consist mostly of quartz, sometimes quite coarsely crystalline. In another specimen from Mt. Waas, identified as a monzonite porphyry, the ground-mass is of microperthite.

Syenite Porphyry

Megascopic appearance. — Some of the syenite porphyries closely resemble the types just discussed, while others, as that from Mineral Mountain, have a decidedly individual appearance. This rock has the general greyish-white color of the other types, but is seen to consist of numerous light-grey to white phenocrysts of feldspar crowded into a slightly darker ground-mass.

The tabular feldspars are evidently orthoclase and are especially prominent both on account of their light color and their size; a number of them have dimensions as great as 11 by 17 millimeters. A dark greenish pyroxene is also a noticeable phenocryst.

Toward Bachelor Basin or toward the northwest the large prominent orthoclase phenocrysts disappear and the rock more closely resembles the monzonite and diorite porphyries.

The Gold Basin occurrence of syenite porphyry shows a rock quite different from that of Mineral Mountain. In this rock pink phenocrysts of orthoclase, sometimes as large as those in the Mineral Mountain occurrence, are scatteringly distributed in a rather dark-grey ground-mass. Upon careful examination the ground-mass is seen to consist of lath-shaped crystals showing a decided fluxion structure.

Microscopic description. — The large phenocrysts in the Mineral Mountain specimens are found to be entirely orthoclase.

Most of the ferro-magnesian minerals are pyroxene, of which aegerine augite is the most important. Small amounts of a greenish-blue hornblende, which may be the soda-amphibole, catophorite, are also found. Magnetite and titanite in slender-twinned crystals are common. Apatite is present as small needles and as crystals almost big enough to be phenocrysts. The ground-mass, which is cryptoperthite, shows a subparallel arrangement.

In some of the more even-textured varieties a little way from the top of Mineral Mountain the rock is found to consist almost entirely of perthite and cryptoperthite. In other specimens the ground-mass is micro-granular and the phenocrysts are entirely of orthoclase. In one specimen enough hypidiomorphic quartz was found to enable one to designate the rock a quartz-syenite porphyry.

In the Gold Basin type the phenocrysts are found to be entirely orthoclase, frequently with Carlsbad twins. Both the phenocrysts and the cryptoperthitic ground-mass show a subparallel to parallel arrangement. In addition to small phenocrysts of aegerine augite, needles which are probably aegerine are scattered through the ground-mass. Magnetite, ilmenite and a hexagonal section with platy to fibrous structure, which may be zeolite altered from sodalite, are also found.

These syenite porphyries do not represent well-defined or unquestioned types. They show the most pronounced affinities for pulaskite or nordmarkite, and on account of their porphyritic texture may be designated pulaskite or nordmarkite porphyries.

Syenite Porphyry Dikes

Of the three dikes in Beaver Basin the two outer ones are quite similar both megascopically and in thin section. They consist of a greenish-grey ground in which are imbedded rhombic to elongated tabular phenocrysts of orthoclase, commonly measuring from 5 to 7 millimeters. Microscopically these rocks are found to consist principally of alkali feldspars (almost entirely orthoclase) as phenocrysts, set in a microperthitic ground-mass. Small amounts of greatly altered hornblende with a bluish-green color may be arfvedsonite. One slide contained phenocrysts of melanite garnet. Tiny needles of aegerine are crowded into the ground-mass which also contains small amounts of magnetite and titanite. Because of their aplitic (syenitic) character these dikes may be designated as syenite-aplite porphyries.

The third Beaver Basin dike, which lies between the two just described, is a light greenish-grey fairly aphanitic rock; no notable phenocrysts are visible. In thin section it is found to consist of phenocrysts of orthoclase (often apparent only in outline, the interior being filled with tiny needles of plagioclase feldspar), smaller phenocrysts of plagioclase and corroded quartz with inclusions, all set in an allotriomorphic ground-mass of quartz and feldspar. Both orthoclase and plagioclase feldspars are found in the ground-mass. Needles of aegerine are scattered through it. This rock might be classed either as a quartz-tinguaite porphyry, or as a grorudite porphyry.

Another unusual rock consisting of a bluish ground scatteringly speckled with small white feldspars was collected from the same locality as the dikes described above. This rock departs so widely from the country rock of the region that it seems likely that it is also a dike rock. I believe it is the same rock that Prindle [19] described as aegerine-granite porphyry, for in thin section it is found to have a fairly even subgranular texture and to consist almost entirely of quartz and feldspar, chiefly

[19] Clarke, F. W., *Analyses of Rocks and Minerals from the Laboratory of the U. S. Geol. Surv. Bull. 419, U. S. Geol. Surv.*, p. 120.

orthoclase. Much secondary calcite makes the further identification of the mineral constituents questionable. A few small phenocrysts of pyroxene and some epidote are sparingly distributed through the rock and tiny needles, which are probably aegerine, are found in small amounts in the ground-mass. Magnetite occurs in very small amounts.

The principal dike in Bachelor Basin is a strikingly "dappled grey" rock which cuts from the northern slope of Castle Mountain across the gully into the upturned sediments that constitute Red Mountain. The spectacular appearance of this dike is due to the presence of large zonally banded phenocrysts of orthoclase, which commonly attain a length as great as one and three-fourths inches. These, together with small phenocrysts of pyroxene, are set in a greenish-grey aphanitic ground-mass. In appearance this rock suggests an orbicular diorite. On either side of this dike are a number of smaller tabular outcrops which differ mainly in the orthoclase phenocrysts, which lose their zonary banding and take on an elongated tabular shape. In thin section most of the pyroxene is seen to be aegerine, though a few zonally banded pheno-crysts were found which showed gradations from augite to aegerine. Phenocrysts of noselite are found also in considerable number. Frequently this sodalite is found altered to zeolite. Magnetite was noted only in very small amounts. The groundmass is found to be microperthite clouded by tiny needles of aegerine. Fluxion structure with eddies about the phenocrysts is characteristic of this ground-mass. Secondary calcite and sericite often give the rock a cloudy aspect. The most nearly applicable name for this rock seems to be noselite-tinguaite porphyry.

Cutting clear through Castle Mountain is a narrow dike which megascopically resembles very closely the grorudite porphyry of Beaver Basin. Microscopically it is found to contain more aegerine, less plagioclase in proportion to the orthoclase, and less quartz as phenocrysts, but much more in the groundmass. This rock shows about equal affinities for the porphyritic facies of grorudite, tinguaite and sölvsbergite.

Near the northwest end of Castle Mountain is a dike with a

blue-grey ground-mass in which are embedded light-colored phenocrysts of orthoclase which commonly show a rhombic outline. These characteristic phenocrysts of orthoclase stand out against their blue ground suggesting grains of wheat, hence the local name coined by prospectors, "wheat grain porphyry."

Under the microscope the phenocrysts are found to be in part perthite, as well as orthoclase. A few oligoclase andesine phenocrysts were also noted. Pyroxene is rare, but epidote is developed in considerable quantities. Magnetite, apatite and ilmenite are common and a small amount of zeolite indicates that sodalite is also present. The ground-mass of this rock is of fine cryptoperthite. Though it suggests in its megascopic appearance a rhombenporphyry, a more accurate name for it seems to be laurvikite porphyry.

The huge slides in the western part of Miners' Basin, referred to above as rhyolite porphyry, show a light-grey to white rock, when not weathered. The weathered surface is grey to yellowish. Perfectly developed prismatic crystals of orthoclase are seen throughout the rock and may be collected in great numbers from the ground, where they have fallen as they weathered out of the parent rock. Quartz in rounded or corroded grains is also a very evident phenocryst. In thin section a few phenocrysts of albite and a little magnetite are also found. The ground-mass is very finely micro-granular.

From the south side of Castle Mountain the writer collected some specimens of a very fine grained slaty-colored rock which seems to be a dike. No individual grains could be detected with the naked eye and even in thin section the rock was found to be so fine-textured as to defy classification. Much grey calcite obscures the major part of the rock, which seems to consist of about equal amounts of allotriomorphic quartz and a turbid feldspar.

A similar rock but lighter in color and even more finely grained was collected from Mt. Tukunikivats. In thin section it appears to be the same sort of rock as the one from Castle Mountain. It seems inadvisable to attempt to classify these rocks without a chemical analysis.

PLACE OF LA SAL MOUNTAIN INTRUSIVES IN THE QUANTITATIVE CLASSIFICATION

From Prindle's collection a rock collected two miles west of Mt. Peale was analyzed by Hillebrand [20] and placed by Prindle as akerose. The writer has examined a number of thin sections from this same general region and all appear to be fairly typical of the diorite porphyry, which constitutes the major part of the intrusive mass. The following analysis from Hillebrand probably represents, therefore, the general composition of the main igneous masses:

SiO_2	61.21
Al_2O_3	17.10
Fe_2O_3	2.72
FeO	1.88
MgO	1.47
CaO	4.83
Na_2O	5.66
K_2O	3.00
H_2O at 105	.34
H_2O above 105	.68
TiO_2	.51
ZrO_2	.02
CO_2	none
P_2O_5	.24
SO_3	none
Cl	.04
MnO	.15
BaO	.13
SrO	.07
Li_2O	trace?
Total	100.05

RELATION OF THE SIERRA LA SAL INTRUSIVES TO THOSE OF OTHER LACCOLITHIC AREAS

The nomenclature of petrography has changed so greatly in recent years that the names used here look little like those employed by earlier investigators to describe the same rocks. This statement is generally true for the other laccolithic areas of this

[20] Clarke, F. W., pp. 120–121 of work cited in note 19.

region. Gilbert [21] identified his Henry Mountain rocks as "porphyritic trachyte." La Sal Mountain intrusives [22] were also first referred to as "porphyritic trachytes." Emery [23] has pointed out that the rocks of the Carrizo Mountain intrusion were called "trachyte" by Holmes and his contemporaries, and that the same rocks were later designated "hornblende porphyrite" by Cross. He further points out that the "hornblende porphyrite" of Cross is the "diorite porphyry" of American petrographers of today.

In his reconnaissance visits to El Abajo (The Blue), El Late (The Ute), and La Plata Mountains, the writer made collections in addition to field-studies. A comparison of these specimens with the diorite porphyries of La Sal Mountains demonstrates some differences in structure and mineral composition, but when the points of similarity are considered the differences become insignificant. These petrological studies have simply reaffirmed the evidence of the remarkable consanguinity of the laccolithic magmas of this part of the United States, a fact pointed out by the earliest investigators and continually substantiated by succeeding investigations.

IV. Structural Geology

Structural Features of the Plateau Country

Instead of being flat-lying, as is one's first impression, the sediments of the plateau country about the mountains are found to be gently folded. Particularly noteworthy are the anticlines which now exist principally as anticlinal valleys. The limbs of these structures are generally low and flat-lying, but they are much more perfectly developed than the intermediate synclines. Longitudinal or strike faults are characteristic of the anticlines and in some cases, as in the upper end of Spanish or Moab Valley, block-faulting has also occurred. All these structures have a general northwest to southeast trend.

[21] Gilbert, G. K., *Report on the Geology of the Henry Mountains, U. S. Geog. and Geol. Surv. of Rocky Mt. Region*, 1907, p. 60.

[22] Peale, A. C., *U. S. Geol. and Geog. Surv. of the Territories, 10th. Annual Report for 1876*, 1877, p. 95.

[23] Emery, W. B., *op. cit.*, p. 357.

On the Utah side of La Sal Mountains, Castle Valley, with its continuation of Salt Valley, and Spanish or Moab Valley are the principal anticlinal structures. Across the Colorado line, Sinbad, Paradox and Gypsum valleys may be continuations of similar Utah structures. The Castle and Spanish valley anticlines are of further interest because of the manner in which their alignment coincides with the axes of the doming of the north and south groups of the mountains. As may be noted from the geological map (Map 3), the axis of intrusion of the northern group is decidedly in a northwest to southeast direction, in direct alignment with Castle Valley. From the mountains of the north group it is seen that the limbs of Castle Valley flatten out as the axis approaches the Colorado River, only to reappear on the western side as Salt Valley anticline. The limbs of Castle Valley have a dip of from 4 to 5 degrees, but when the structure reappears on the farther side of Colorado River the dip is practically doubled, with the result that the anticlinal character of Salt Valley is much more pronounced than that of Castle Valley. Its limbs project high above the surrounding plateau country, so that it may easily be seen for many miles from almost any direction.

An interesting detail in the structure of Castle Valley is Porcupine Ridge which lies along the south rim adjacent to the mountain group. This ridge seems to be a portion of the valley wall which has faulted or slid downward.

As one looks eastward from the tops of the mountains of the north group into Colorado, the anticlinal Paradox Valley is a very prominent feature. It seems to be a continuation of the Castle Valley and the north group anticlinal structure. No opportunity was afforded to follow the axis of the Utah structure into Colorado, but from the mountains excellent views of all these structures may be obtained and the relationship suggested above seems a very reasonable one. Though the relationship is not clear as was the case with the north group, the doming of the south group is seen to be in alignment with the axis of Spanish Valley. The probable continuation of this structure into Colorado is not so clear as in the case of the northern group.

All these anticlinal valleys are traversed by conspicuous faults. Prommel,[24] who has studied these structures farther away from the mountains and also the anticlines down the Colorado from Spanish Valley, notes that the vertical displacement of the faults increases toward the mountains and that the structures down the river, which are entirely outside the area of possible effect from the mountain uplift, are practically unaffected by faulting. This suggests that the faulting is intimately associated with the mountain uplift. The vertical displacement along these strike-faults varies from almost nothing to 3,500 feet. A great fault with strike parallel to the axes of the anticlinal valleys passes south of the mountains in the vicinity of the property of the Big Indian Copper Company. Another similar break of undetermined displacement was noted north of the north group.

As regards minor structures the sediments of the plateau country are in many cases conspicuously jointed. As already pointed out, these structures have had a very marked effect on the weathering and erosional processes. The Wingate (Pl. V, Fig. 2) and the Navajo exhibit especially well developed vertical joints. These two formations constitute the principal cover rocks north and west of the mountains, so that weathering and erosion have caused the joint systems to become more noticeable than in other formations.

Structure of the Mountains

Though La Sal Mountains have always been considered laccolithic in origin, they exhibit many structures which depart widely from those which true laccoliths should have. The north group, except for Mt. Haystack, and the south group, may be considered as true laccolites. It is within the central group that the different structural conditions are developed.

In neither the northern nor the southern group is the floor of the igneous core of the mountains exposed. The horizon of intrusion is inferred to be immediately below that represented by the stratification contacts found around both these groups. The ridge southeast of Beaver Basin, Red Mountain, Burro Pass and

[24] Prommel, H. W. C., *op. cit.*, p. 393.

the ridge just back of the Warner Ranger station all show actual contacts. The contact rock is found to be a series of grey to maroon arkoses, grits, conglomerates, sandstones, shales and some limestones. Lithologically the beds seem to be equivalent to the Cutler as studied in Castle Valley and elsewhere about the mountains. Furthermore, Little Round Mountain is probably the product of the same period of igneous activity as that which caused the formations of the mountains proper, and though its floor is not exposed, beds of undoubted Permian age are exposed at a distance from it and are seen to dip away as though it had been involved in its formation. In the discussion of the sedimentary rocks associated with the mountain region, it was pointed out that the Cutler beds resemble the Rico lithologically to so marked a degree that it is often difficult to delimit the two formations. And though no beds of known Rico age were found about any of the contact zones, it is not advisable to assume definitely that the Rico has not been involved in the formation of the mountains. On the basis of the thickness of the exposed shaly contact zone it is believed that the igneous mass is either intraformational, i.e. in the lower part of the Cutler, or interformational, i.e. between the Cutler and the Rico. Overlying this shaly horizon of intrusion come the thinly bedded rocks of the Shinarump and the Chinle, above which are the massive competent Wingate and Navajo sandstones.

Grits, conglomerates, sandstones and shales similar to those exposed about the north group are found at the contact zones southwest of Mt. Tukunikivats of the south group, from which it is inferred that the horizon of intrusion is here the same as in the north group.

In both the end groups with the upturned sediments about them, the shaly zone in contact with the igneous core has eroded much more rapidly than the competent Wingate and Navajo sandstones farther removed. Pronounced hogbacks have therefore been developed in many places (Pl. VIII, Fig. 2).

In all the contact areas about both the north and the south groups the upturned sediments were found to be dipping steeply. In no place was a dip of less than 45 degrees noted and along the

western side of the north group the sediments are in some places practically vertical (Pl. VIII, Fig. 1). The intrusion into this group was essentially unsymmetrical with the steeper side along the western flank. In the south group the intrusion seems to have been more nearly symmetrical and in no case were the sediments found to be dipping so steeply as along the western flank of the north group. The change in dip from the steeply dipping conditions about the mountains to the nearly flat-lying position of the strata in the adjacent plateau country is very abrupt, especially along the western side of the north group. Immediately north of the north group just above the village of Castleton, the dip of the sediments, instead of flattening out into the characteristic mesa-like structures found elsewhere, reverses, with the formation of a rather sharp syncline.

Though the contacts around the north group are characteristically stratification contacts, it will be noted that along the northern border of the intrusion the rising magma broke across the strata in several places instead of doming them upward. This part of the mountain mass is also intersected by a number of short dikes, one of which at least, as already noted, not only cuts the porphyry mass but extends outward into the upturned sediments that constitute Red Mountain.

Mention has already been made of Little Round Mountain and though it does not come within the area covered by the map, it is no doubt an intimate associate of the mountain group proper, and at greater depth might show a more intimate relationship with the igneous core of the north group than now appears to be the case. So far as they can be observed, the structural features associated with this igneous butte are identical with those that characterize the north group proper.

As already noted, Mt. Haystack, though apparently a part of the north group, is yet quite different structurally from the remainder of the intrusion. An immense amount of slide rock has covered the contacts on every side except for a few feet of McElmo and Dakota beds which are exposed along the south side. These are not sufficient to give a definite clue as to the exact structure of the mountain. It appears to have been an

intrusion which was so rapid that it cut across the sedimentary rocks instead of doming them up, except for small portions of the upper formations, i.e., the McElmo and the Dakota, which were locally so sharply upturned by the intrusion that the only outcrops visible have a vertical dip. Mt. Haystack seems therefore to be essentially a stock (Fig. 2).

In the south group what appears to be a finger from the main intrusive mass underlies Moore's Ridge (Fig. 3). The anticlinal character of this ridge is very evident, with the rocks dipping away on either side. The crest of the ridge is covered with the Navajo sandstone which is separated into great blocks and which seem to have resulted from tensional stresses brought about by the force of the upwelling magma below.

It is in the central group that the conditions of intrusion seem to have been particularly complex. Wherever they are exposed about this group the sediments are found to dip toward the igneous core at an angle of about 5 degrees. When these dipping beds are followed toward the intrusive center, it is found that the exposed porphyry masses are above the level of most of these dipping sediments, that is, the exposed igneous masses do not seem to have caused the slight doming of these sediments. The suggestion at once arises that the exposed portion of the intrusion represents but a part of the main intrusive mass and that at greater depth below the gently domed strata exists another horizon of intrusion. A study of individual mountains substantiates this view; a particularly interesting example is Mt. Mellenthin.[25] From the Horse Canyon side the entire floor of this mountain is clearly exposed and the horizon of intrusion is seen to be at the base of the Mancos shale, just above the Dakota Sandstone. Considerable quantities of the Mancos shale are included in the porphyry mass at different levels. The feeders which supplied the magma to form this mountain are represented by a number of dikes which are clearly exposed along the east wall of Horse Canyon. These dikes cut upward from some unexposed source through the McElmo and the Dakota

[25] Gould, L. M., "A 'Laccolite in the Air,'" *Papers of the Michigan Academy of Science, Arts and Letters*, 5: 253–256.

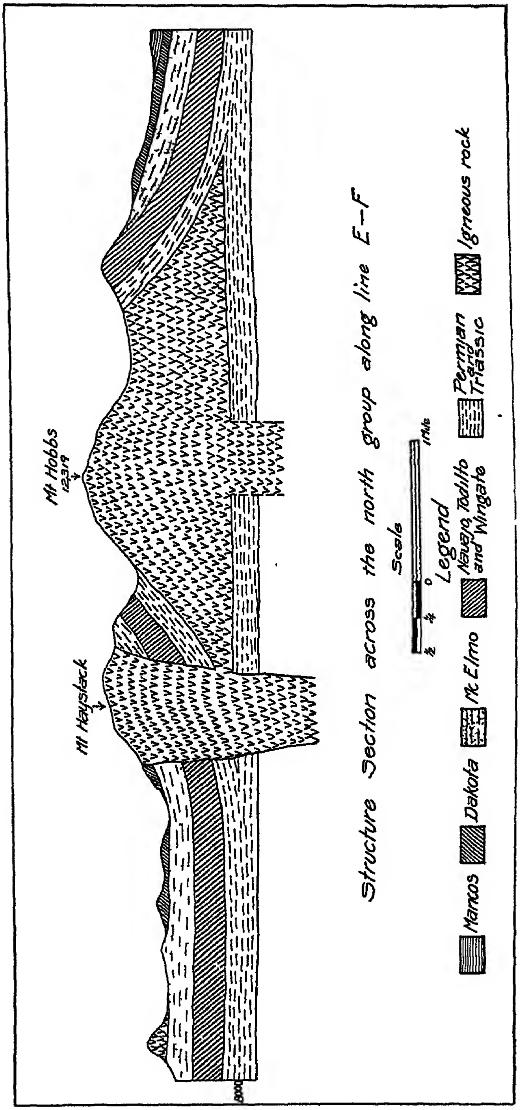


FIG. 2. Structure section across the north group along the line E–F of the geologic map

into the Mancos where the magma spread laterally. The thickest portion of the possible buried mass beneath the mountains of this group appears to be south of Mellenthin in the direction of Mt. Peale, for it will be noted from the structure section (Fig. 4) that the floor of Mt. Mellenthin is dipping upward in the

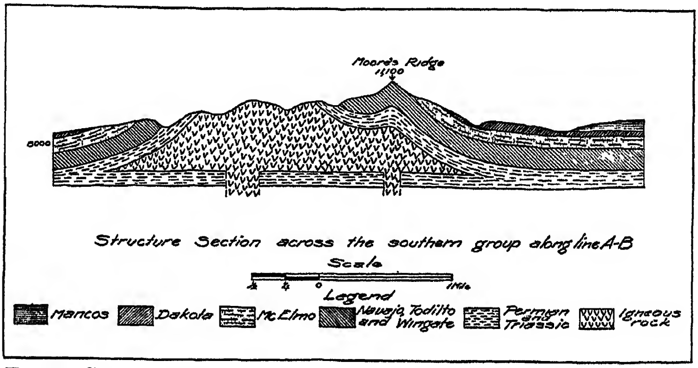


Fig. 3. Structure section across the south group along the line A–B of the geologic map

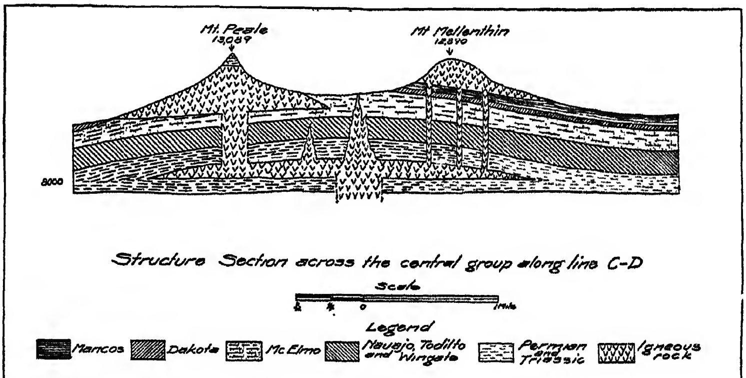


Fig. 4. Structure section across the central group along the line C–D of the geologic map

direction of Mt. Peale. The latter mountain is the highest in the entire La Sal area and unlike any other peak it is capped by flat-lying sediments. These sediments are somewhat metamorphosed and discolored, but are believed to be from the lower portion of the McElmo. They do not, apparently, represent part of a fold that once covered the mountain, but they seem rather to have been broken off and carried upward by the immense force of a rising magma from below. A small exposure of practically flat-lying sediments is found on the southwest flank of this mountain. This may be the formation from which the strata on the top of Mt. Peale were broken off. Furthermore stratification contacts are notably lacking about Mt. Peale. In only one place and there for but a few feet were any sediments dipping away from the igneous mass with such contacts. Rather the beds involved in the intrusion are but slightly tipped up, the magma for the most part having broken across them.

The third principal peak of the central group, Mt. Allen, presents still more complex structural conditions than either of the other two. On the south and west sides the McElmo beds are slightly upturned about the porphyry core, but not to such an extent as to form stratification contacts. On the south side, where erosion has cut deeply into the mountain, a wedge-shaped dike cuts upward into the sediments and sends out small lateral sheets into the shaly beds of the McElmo. On the Gold Basin side of the mountain this sort of structural feature is more pronounced. Toward the head of this basin, where one may see a considerable vertical section through the structure, sheets are seen to spread out into the McElmo beds from Mt. Allen and from dikes which cut upward through the masses of sediments and interstratified sheets. Though the McElmo beds seem to be the principal ones in immediate contact with the porphyry mass of Mt. Allen and the strata into which the rising magma mainly intruded itself as sheets, beds much lower stratigraphically seem to have been disturbed in the formation of this mountain, that is, it does not seem to be the product of a magma which rose through one or through a number of conduits and which upon reaching the McElmo in part insinuated itself into this

formation and in part domed it up. On the western flank of Mt. Allen considerable portions of a maroon conglomerate with boulders as much as eight inches in diameter were found. I know of no formation in this general region from which such a rock might have come except the Cutler. It seems, therefore, that Mt. Allen is the result of an intrusion of stock-like character, which probably does not possess associated magma sheets except within the McElmo. Its rise through the beds above the Cutler, until it reached the McElmo, was so rapid as to cut completely across them except for the small area noted on the west flank.

The isolated patches of igneous rock which lie to the west and northwest are probably parts of the same intrusion as that which constitutes Mt. Allen. Further erosion will very likely reveal a more intimate relationship at greater depth.

It has been pointed out that the porphyry mass capping the lower end of the ridge north of Gold Basin is a flow. Its floor is plainly seen to be the McElmo beds which are entirely undisturbed about it. A pronounced fluxion structure also characterizes this rock.

The small igneous mass at the upper end of this ridge was probably formed contemporaneously with Mt. Mellenthin, for it is in the same horizon. The formation of Horse Canyon has separated it from the major part of the intrusion. The ridge that extends northeast of Mt. Mellenthin is seen to be composed principally of igneous rock. This mass seems, however, to have no intimate relationship with Mt. Mellenthin, for it has disturbed the McElmo beds about it; that is, its horizon of intrusion is below the base of Mt. Mellenthin.

The dikes which are associated with this group of the mountains are in part radial, as is seen, from visible igneous masses (see Map 3). In part they seem to be roof dikes to some unexposed mass below. Particularly interesting in this connection is the dike which strikes northwest-southeast along the upper north side of Gold Basin. It appears to be a wedge-shaped dike thinning rapidly toward the top. Its exposure does not at any place studied exceed thirty feet in width. Some years ago a

mining company drove a tunnel into and near the bottom of the north wall of Gold Basin approximately at right angles to the probable continuation of this dike. In the summer of 1921 it was still possible to go into this tunnel, which penetrates nearly a hundred feet into the porphyry mass with the end of the tunnel still in the igneous rock. This igneous body appears to be the lower portion of the narrow dike outcrop several hundred feet higher up the side of the basin.

From a general view of the structure of this entire group it seems that, just as was the case in the end groups, there was an intrusion in or below the Cutler beds, but for reasons which will be given later the intrusion did not here greatly dome up the overlying strata. Instead, the magma broke through the roof of this lower horizon so as to well upward through the smaller fissures and form dikes. Through others it formed conduits or feeders, intruding itself at different horizons according to local conditions of structure, viscosity of the magma, or as the rate of intrusion may have controlled. Mt. Allen seems to have been a breaking upward from a small portion of the lower intrusion itself. In the case of Mt. Peale the magma welled upward until it reached the lower part of the McElmo, where it spread out and continued to rise with such great force as to break off and carry upward the flat-lying sediments now found upon its top. In the formation of Mt. Mellenthin the rising magma did not spread laterally until it had reached the Mancos shale. The three main mountain masses of this group illustrate gradational phases between true laccoliths and stock-like structures. Mt. Allen suggests a stock; Mt. Peale represents a more intermediate stage, an imperfect sort of laccolith, while Mt. Mellenthin appears to be a true laccolith. As already noted the porphyry of this mountain is intruded into the Mancos shale. To judge from the attitude of a few outcrops of this shale to the north of the mountain, it seems to have covered the igneous core and formerly it may also have had small intruded sheets of porphyry, which have since been eroded.

V. The Origin of La Sal Mountains

REVIEW OF THEORIES ON THE ORIGIN OF LACCOLITHS

Powell [26] seems to have been the first investigator to make any suggestion concerning the possible origin of the laccolithic mountains of the southwestern part of the United States. He thought the Henry Mountains, which he named, were formed by quantities of molten matter pouring out through fissures and spreading over the country before it had been eroded to its present depth. Later investigators of the Hayden Survey pointed out the error of Powell's suggestion and demonstrated the intrusive character of these mountains. Peale [27] in 1877 assembled the information available concerning these so-called "eruptive" mountains of the southwest. He concluded that they were all the result of igneous material which came up through fissures in the sedimentary rocks, in some places only slightly tipping up the ends of the strata, and which upon reaching the Cretaceous shales generally spread out in them.

It was Gilbert [28] however who first gave a statement of the more exact character and probable cause of this type of mountain. His idea is so concisely stated that it merits quoting in his own words. After pointing out that it is usual for igneous rock to ascend to the surface of the earth and there issue forth to form mountains or hills, he adds: "The lava of the Henry Mountains behaved differently. Instead of rising through all the beds of the earth's crust, it stopped at a lower horizon, insinuated itself between two strata, and opened for itself a chamber by lifting all the superior beds. In this chamber it congealed, forming a massive body of trap. For this body the name *laccolite* (from two Greek words meaning cistern and stone) will be used."

[26] Powell, J. W., *Exploration of the Colorado River of the West and Its Tributaries, 1869-1872*, pp. 177–178. Smithsonian Institution.

[27] Peale, A. C., *On a Peculiar Type of Eruptive Mountain in Colorado. U. S. Geol. and Geog. Surv. of the Terr.*, Bull. No. 3, III: 550–564.

[28] Gilbert, G. K., *Report on the Geology of the Henry Mountains, U. S. Geol. and Geog. Surv. of the Rocky Mt. Region*, 1877, p. 19.

In 1893 Cross [29] published a very comprehensive account of the geology of the laccolithic areas of the southwestern part of the United States, in which he suggested a new force operative in the formation of this type of mountain. Gilbert ascribed the entire doming of the strata to the hydrostatic force of the rising magma, but Cross believes that orogenic stresses are necessary, in a few cases at least, to account for the doming of the sediments over some of the laccoliths which he describes. He does not appear ready, however, to go so far as Steinmann [30] in the matter of the relationship between folding and igneous intrusion. The latter, in discussing the relationship between the Andes and their igneous core, expressed the belief that the space for the intrusive mass was formed by the folding itself. Hobbs [31] would carry over to laccolithic mountains the ideas expressed by Steinmann with reference to Andean structure; that is, he ascribes to regional compressional stresses the entire cause of the doming of the strata over laccolithic mountains. He believes further that the laccolithic magmas themselves are not the products of intrusion in the ordinary sense, but rather that they have resulted from the fusion of shales upon the pressure being relieved by the doming of the competent structures above. McCarthy [32] has recently given an excellent review of the various notions concerning laccoliths and has further pointed out the importance of such factors as the rate of intrusion, and the viscosity of the magma, as well as of orogenic stresses in the effects that all these may have had upon the structures resulting from intrusions. His conclusions are based further upon experimental data which in part seem to have excellent representatives in some La Sal Mountain structures, as will be pointed out later.

[29] Cross, Whitman, "The Laccolithic Mountain Groups of Colorado, Utah, and Arizona," *Fourteenth Ann. Rept. Direction, U. S. Geol. Survey*, Part II, 1893, pp. 165–238.

[30] Steinmann, G., "Gebirgsbildung und Massengesteine in der Kordillere Südamerikas," *Geol. Rundsch.*, 1 (1910): 13–35.

[31] Hobbs, W. H., *Earth Evolution and Its Facial Expression*, pp. 53–58.

[32] McCarthy, G. R., "Some Facts and Theories concerning Laccoliths," *Journ. of Geol.*, XXXIII (1925): 1–18.

APPLICATION OF THESE THEORIES TO LA SAL MOUNTAINS

The structural conditions of the central group of La Sal Mountains are so different from those of the end groups that one is forced at the outset to the conclusion that greatly differing conditions of formation obtained in the various groups. In other words, no one of these theories, without some modifications, explains all La Sal Mountain structures.

The Central Group

It has been pointed out that the north and south groups show a definite alignment with anticlinal structures of the plateau region. Here the relationship of orogenic stresses to the formation of the mountains is evidently a very intimate one. In the central group there is no evidence that such stresses played any part. The plateau areas adjacent to this group are flat-lying or even slightly synclinal, since they represent the region between the well-developed Castle Valley and Spanish Valley anticlines. The structures of this group seem to be explained by Gilbert's theory in which the hydrostatic force of the ascending magma was the sole cause of the rupturing and upturning of the sediments. McCarthy's experiments, as described in the paper referred to, suggest that the rate of intrusions has a great effect upon the character of structures. Other things being equal, if the intrusion be sufficiently slow the round-arch type of laccolith represented by the Henry Mountain is formed. At the other extreme with too rapid rate of intrusion stocks result. In the central group of La Sal Mountains, except for the postulated lower horizon of intrusion which, if present, is a thickened sheet or a greatly thinned laccolith, the structures indicate that the rate of intrusion was too rapid to allow a complete doming of the overlying strata with the development of stratification contacts, after the fashion of the Henry Mountains. Mt. Mellenthin may be an exception to this statement, for though the strata above its horizon of intrusion are almost entirely eroded, the remnants suggest that it represents the Henry Mountain type of structure. As regards the other mountain masses of this

group, the ascending magma rose with such force that it cut across the sediments in some places, insinuated itself between the strata in others, and in still others tipped up the surrounding sediments, but rarely with the formation of stratification contacts. These mountains really represent intermediate stages between true laccoliths and stocks.

The North and South Groups

So far as the end groups of the mountains are concerned, Gilbert's theory of the doming of the strata as due solely to the force of an ascending magma, is clearly inadequate. It is hardly conceivable that the intrusion of so great a mass as that represented by either of these end groups could take place uninfluenced by outside factors, especially with the formation of sediments so steeply upturned about the igneous cores, without the formation of numerous radial dikes. When one considers the great differences between the structures of the central group as compared with the north and south groups, it is at once apparent that the anticlinal structures of the plateau country associated with these two groups truly indicate that orogenic stresses have played a very important part in the doming of the strata over the igneous cores. It is, therefore, apparent that the structural features of the end groups accommodate themselves more nearly to the theory of the fusion of shales or to the idea that orogenic stresses even to the point of folding accompanied or preceded the intrusion of the magma. It should not be inferred from this statement that the writer believes that folding must proceed to such a point as completely to form reservoirs in order that such structures as those represented by the end groups of La Sals may form. Indeed the hydrostatic force of a rising magma may have been the major force, with the orogenic stresses in the nature of incipient folding simply acting as a rudder.

Quite like the other laccolithic mountains of the southwestern United States, extensive contact metamorphic effects are notably lacking in all three groups of La Sal Mountains. There have been bleaching and discoloration of the red rocks of the contact zones in the north and south groups and in a few

places, notably Red Mountain of the north group, some shales have been changed to slate and small amounts of iron ores have been developed. But these contact effects are much less pronounced than one might expect to be produced by the intrusion of so great a mass as that represented by the north group especially. It has been customary for investigators to explain this general absence of great contact metamorphic effects about laccoliths on the basis of the temperature of the intruding magma; the supposition has been that magmas might be intruded at so low temperatures and with so small an amount of mineralizers that no appreciable contact metamorphic effects were produced. Hobbs takes a different view and attaches great importance to the absence of such effects in support of his theory of the fusion of shales.

The inference from this theory is that the temperature of a magma formed in such a manner would so closely approximate that of the country rock that the tendency for contact metamorphic effects would be reduced to a minimum.

Cross [33] has shown that the geologic horizons occupied by laccoliths range in age from the Cambrian to post-Laramie. So far as they are expressed by the structure, the conditions of cooling in the highest were identical with those in the lowest. The conclusion is inevitable, therefore, that several thousand feet of sediments must have covered the highest of these laccoliths at the time of their formation. In view of the depth below the surface necessited by so great a load, the temperatures at the horizons of intrusion of the various laccoliths may well have been so high that magmas could easily have been intruded at temperatures approximating those of the country rock. Furthermore, if the igneous masses which now constitute the cores of laccoliths were formed by the fusion of adjacent bodies of shales, some evidences of such fusion ought to be preserved. Gradational phases between the shales and their igneous equivalents should be found especially about the contacts and in connection with the masses of shales included in the porphyry bodies. Cross [34] notes that the statements of Peale and Holmes that the magmas

[33] Cross, Whitman, *op. cit.*, p. 239. [34] *Ibid.*, p. 230.

"absorbed" sedimentary masses are not supported by definite evidence of fusion. Neither in such masses of shales as those found included in the porphyry body of Mt. Mellenthin, nor about any of the contacts in La Sal Mountains is there any evidence of such fusion. The contacts between the two kinds of rock are sharp and furnish easy planes of parting. El Abajo and El Late Mountains are intruded into Cretaceous shales. None of the contacts studied about either of these groups showed any evidence of assimilation of the shales by the igneous mass. In La Plata Mountains brief studies were made of Mt. Hesperus and Banded Mountain with their remarkable banding due to the interbedded shales and sheets of porphyry. Though some slight metamorphic effects are noticeable, the lines of demarcation between the shales and the igneous rock are generally well defined and give no suggestion of an intimate genetic relationship.

CONCLUSIONS

In trying to arrive at a proper conclusion with reference to the origin of La Sal Mountains, I have dealt with the various groups as though they might not be intimately associated. Such is not the case. Indeed the igneous cores of the three groups, at the horizon of intrusion of the north and south groups, may be connected beneath the sedimentary saddles. There is no evidence that the entire mountain uplift is not the result of a single or of a number of closely spaced periods of igneous activity. Viewed as a whole then, La Sal Mountains seem to be unusually well developed examples illustrating the profound effects that orogenic stresses may have upon the structures produced by laccolithic intrusions. The differences in the structure of the end groups as compared with the central group may be entirely accounted for by the fact that in the central group the intrusion was uninfluenced by folding stresses, hence the complex structures and semi-stock-like character of parts of this group. In the end groups horizontal compression to the extent of folding affected the intrusions in such a manner as to allow the doming of the surrounding strata without the development of widespread tensional effects.

THE AGE OF LA SAL MOUNTAINS

The youngest rocks exposed anywhere near the mountains are the Mancos shales of Cretaceous age. These have been involved in the mountain uplift. Therefore beyond the statement that the intrusion was at least post-Cretaceous, nothing definite can be said about the age in which the Sierra La Sal were formed. Cross [35] has pointed out that the West Elk Mountains in Colorado are certainly Tertiary in age and that everything suggests that the other groups, including La Sal Mountains, are of the same age.

The field-work upon which this report is based was conducted during the summers of 1921 and 1924, which were spent in La Sal Mountains and in neighboring regions. This extensive work was made possible only because of the very generous financial assistance of Mr. R. C. Allen of Cleveland, in whose honor Mt. Allen is named.

University of Michigan

[35] Cross, Whitman, *op. cit.*, p. 238.

PLATE I

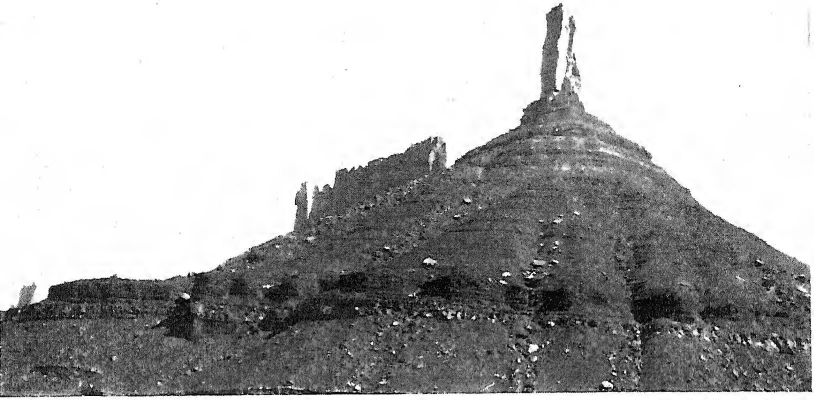


Fig. 1. Castle Butte in Castle Valley

Fig. 2. Arches in the Upper Navajo Sandstone

PLATE II

FIG. 1. Mt. Hobbs at the Head of Beaver Basin, showing Schrund Line

FIG. 2. Typical Forms of the Navajo on the "Sand Flats," Where It Is the Cover Rock

PLATE III

FIG. 1. Cirques at the Head of Deep Creek Basin

FIG. 2. Gold Basin showing U-shaped Valley and Cirque

PLATE IV

Fig. 1. Pratt's Lake in Dark Canyon, a Morainal-dam Lake

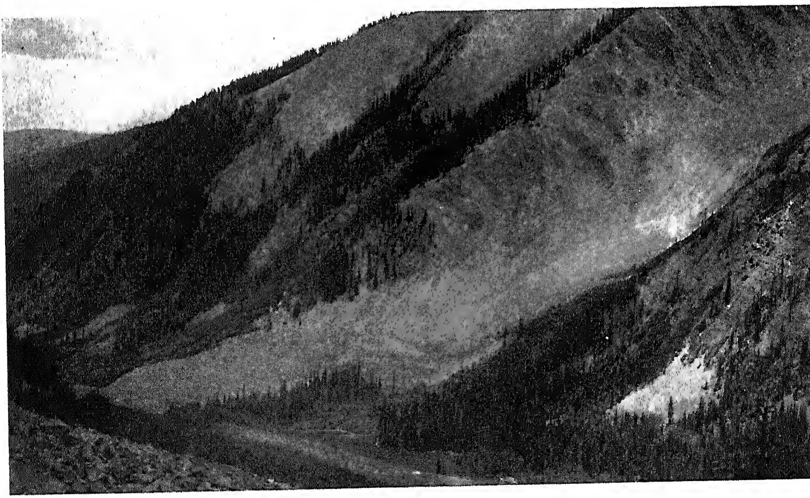


Fig. 2. Rock Glacier in Lower Part of Deep Creek Basin

PLATE V

FIG. 1. Unconformity between Permian and Triassic exposed in Colorado Canyon

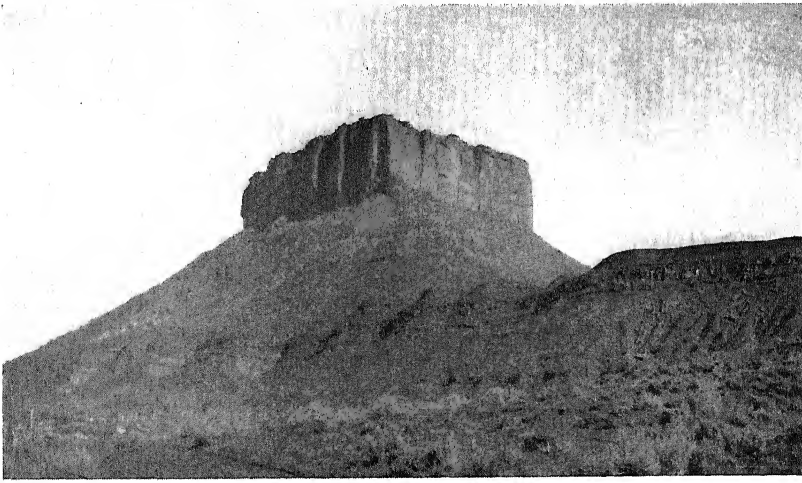
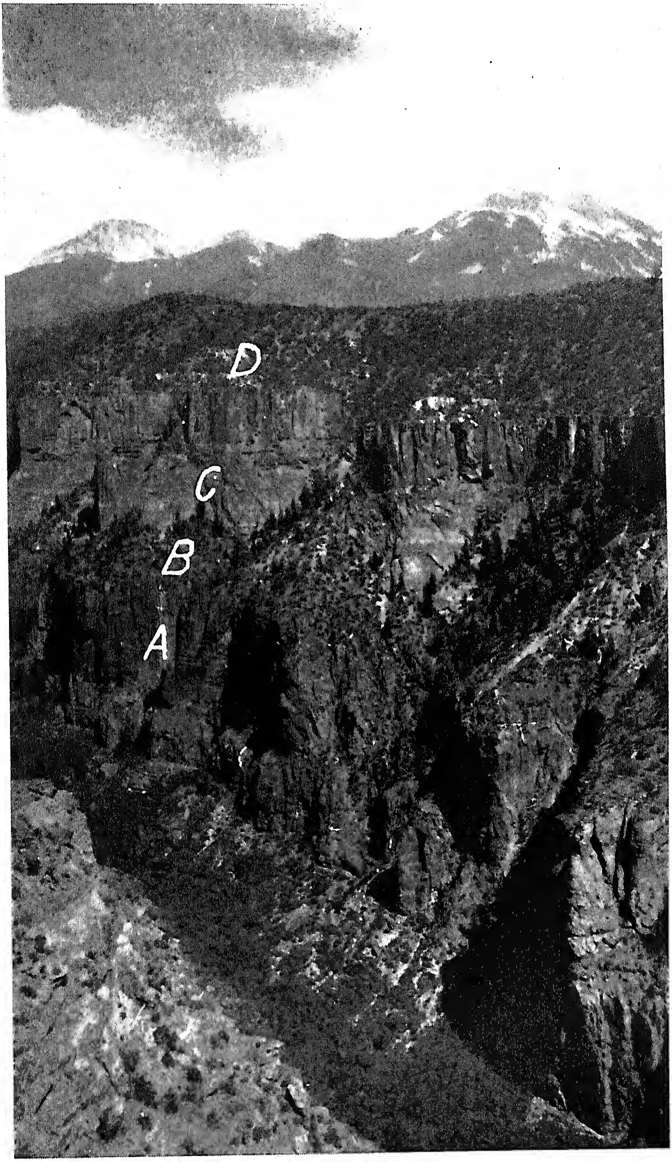


FIG. 2. Mesa in Lower End of Castle Valley
The lowest rock exposed is Cutler and the cap rock is the Wingate

PLATE VI



The Canyon of Mill Creek near the Central Group

A is the Lower Navajo; *B*, the Middle Navajo; *C*, the Upper Navajo; *D*, the McElmo

PLATE VII

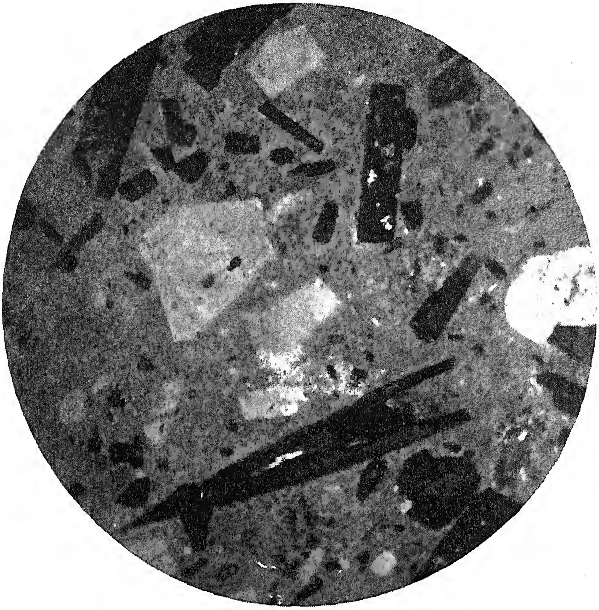


FIG. 1. Photomicrograph of Diorite Porphyry showing Acicular Development of the Hornblende

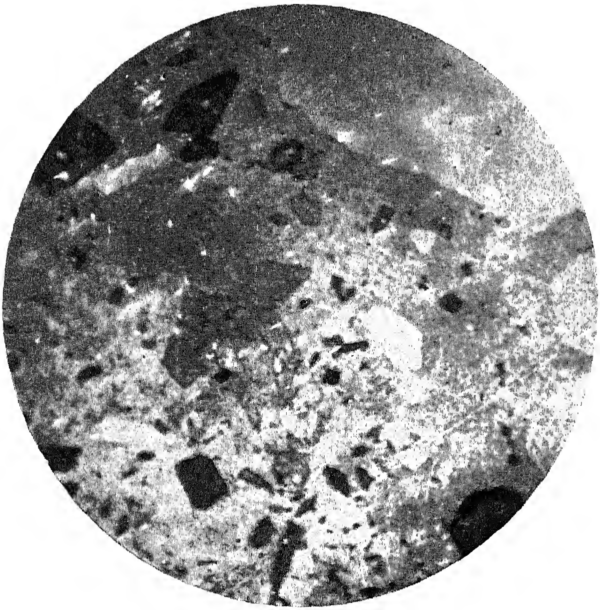


FIG. 2. Photomicrograph of Diorite Porphyry showing Characteristically Twinned Crystal of Augite

PLATE VIII

FIG. 1. Hogback of Dakota Sandstone along the Western Side of the North Group

FIG. 2. Hogback of Massive Triassic Sandstone along the Southern Side of the North Group

ICE-PUSH ON LAKE SHORES

IRVING D. SCOTT

FOR some time the writer has had the conviction that ice action on the shores of the smaller inland lakes was quite prevalent and, therefore, deserving of greater consideration in the texts on geology than is generally the case. This conviction has been amply confirmed by a study of several years' duration of a large number of the inland lakes of Michigan, few of which worthy of the name lake are without evidence of ice-push on their shores.

PROCESSES

Two theories have been advanced for the shove of ice on the shores of lakes, namely expansion and ice-jam. Both theories appear to be well established by observation, but that of expansion, which appeared first, seems to have received almost exclusive recognition. If, then, two processes are active in forming similar features, the question arises, aside from the mechanics of the processes, as to their relative importance. The writer's observations have some bearing in this connection as well as on the mechanics of the processes and, therefore, some discussion of the action of ice and its results on shores is attempted in this article.

The expansion theory accounts for the shove of the ice on shores by the contraction and expansion of ice due to variations in air temperatures. Recent papers on this subject have been written by Buckley (1, pp. 141–162), Gilbert (2, pp. 225–234), and Hobbs (3, pp. 157–160), and of these Buckley's is the most comprehensive.

This theory is based on the fact that ice under normal pressures acts as do other solids under varying temperatures below

the freezing point, expanding with a rise in temperature and contracting when the temperature falls. The linear coefficient of expansion as given by Landolt–Bornstein–Roth varies from .0000237 to .000054 per degree centigrade with an average value of .0000417. In using the average value, the linear expansion of an ice sheet one mile in diameter is .12 feet for each degree Fahrenheit rise in temperature. The expansion attendant on water changing into ice has little or no effect on the shores, but the resultant ice-sheet forms a complete cover over the lake and increases in thickness by addition to the lower surface. A subsequent lowering of temperature of the air is transmitted to the ice from the upper surface downward, giving temperatures in the ice ranging from approximately that of the air at the upper surface to 32° F. at the lower surface where the ice is in contact with the water (1, p. 151). Thus, a differential horizontal contraction is set up which is greatest at the upper surface and decreases downward to zero at the bottom of the ice. This tends to deform the ice-sheet concave upwards (4, pp. 29–49). This deformation is opposed by gravity and the buoyancy of the water, and horizontal stresses result which are tensile at the upper surface and compressive at the lower, with an intermediate zone of no lateral stress. When the tensile strength of the ice is exceeded, a V-crack is formed and extends downward to the zone of no lateral stress, which itself is simultaneously lowered until the stresses are relieved. If sufficient tensile stress is developed, the zone of no lateral stress and the crack as well extend to the lower surface of the ice. In this way cracks develop in sufficient number to reduce the stresses below the tensile strength of the ice and the ice surface remains nearly flat, except locally on either side of the cracks where it may curve upward.

It has been noted (5, Append. 7, p. 23) that at times lanes of water are opened along such cracks with a drop in temperature at night, but are closed during the warmer temperatures of the day. Since the temperature of the lower surface of the ice remains constant at the freezing point, there should be no variation in volume in this zone and, consequently, no spreading of

the cracks nor pulling away from the shores. In explanation it may be suggested that the apparent contraction of the lower layer is due to the appreciable compressibility of the ice, which, according to Ludlow (6, p. 923), is one twelfth of its volume under pressures varying from 21 to 64 tons per square foot (temperature probably 32° F.). Also there is the possiblity of melting due to the lowering of the melting point by compression on the lower layers previous to the relief of the tension in the upper layers by fracture. In either case no values can be given for the compression, so that the importance of these factors cannot be stated.

Where the V-cracks extend through the ice the water rises about nine tenths of the total thickness of the ice and freezes, forming wedges of ice with points down. As the temperature lowers, old and new cracks are opened and healed, and the ice cover remains constant in linear extent but increases in average density. When the temperature reaches its lowest point, the surface of the lake is completely covered with ice of maximum average density.

With a rise in temperature, expansion of the upper layers takes place and with it a tendency to deform the ice-sheet convex upward. This tendency is intensified by the presence of the wedges mentioned in the preceding paragraph. Stresses are, therefore, set up which are the opposite of those active during contraction, namely, horizontal compression in the upper layers and tension in the lower. When the stresses exceed the tensile strength of the lower layers, inverted V-cracks are formed from below, which are probably healed in most cases. In this way a permanent expansion results which is equal in amount to the total thickness of the ice wedges formed at the upper surface, as shown in Figure 5. The process may be repeated a number of times during a winter and the amount of expansion is proportional to the total rise in temperature below the freezing point, provided the temperatures are promptly transmitted to the ice.

If sufficient expansion takes place, either the rigidity of the ice is overcome or the edge of the ice expands on the shore. In

either case the stresses are relieved suddenly (1, p. 151). In case the rigidity of the ice is overcome it usually buckles or arches, although troughs have been noted (5, p. 23). The prevalence

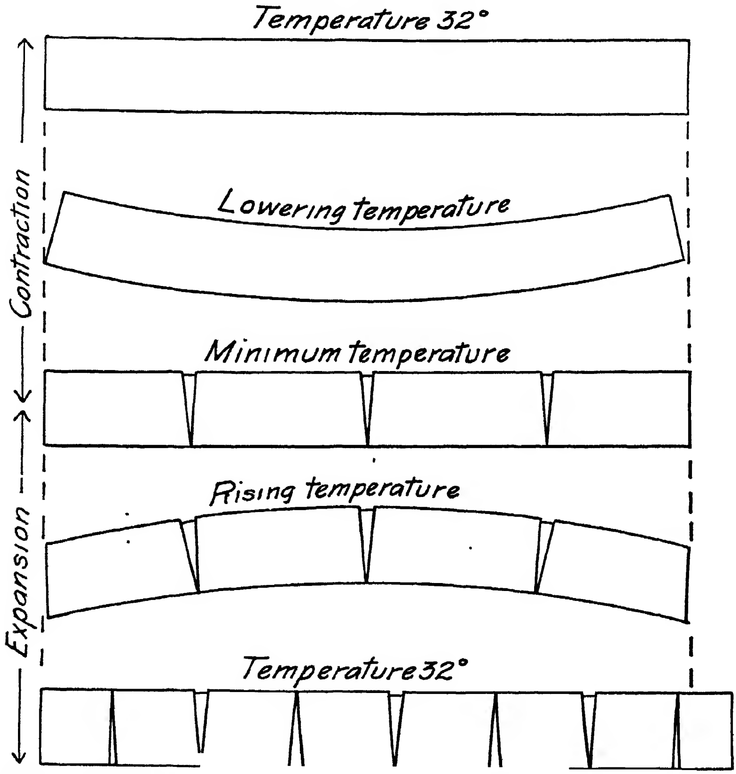


FIG. 5. Drawing (after Barnes) showing the linear expansion of an ice-sheet due to lowering temperature followed by a rising temperature

of anticlinal structures is due to the tendency of the ice-sheet to assume a convex upward surface during expansion, the presence of wedges in the cracks placed head up, and the upward warped edges of the cracks. The troughs, which occur infrequently, are caused by one wall of the cracks slipping under the other (7) and

resemble thrusts rather than synclinal structures as suggested by Meigs. On the other hand when the ice expands on the shore, it pushes before and carries with it earthy material which, upon the melting of the ice, is left at the most advanced position of the ice edge.

The conditions under which this expansion on the shores takes place have been stated by Hobbs (3, pp. 157–160) and may be grouped under two headings, climatic and mechanical. The climatic elements are a winter season during which a complete cover of ice of considerable thickness is formed, large and relatively rapid alternations of temperature below the freezing point, and an absence or light accumulation of snow on the ice. The seasonal variation in temperature is quite generally fulfilled in north temperate latitudes above 42° or 43°. For large and relatively rapid temperature changes during the winter, there are cyclonic and diurnal variations as possibilities. Buckley's studies have shown, however, that the cyclonic variations are particularly effective and that the diurnal changes have little or no effect (1, pp. 141–162). Further, of the cyclonic changes it is those attendant on a low pressure closely following a cold spell that are effective. An analysis of the temperature record taken at Madison, Wis., for the months of December, January and February, 1898–99, given by Buckley (1, p. 143), shows a total range of more than 1200° F., excluding temperatures above 32°. Inasmuch as the daily range represents both a rise and fall of temperature of like amount on the average, it is indicative of the amount of expansion that might be expected if all the energy were expended in this way. The 1200° should produce a total expansion of about 144 feet, or 72 feet on each shore of a lake one mile in diameter where the ice is free to move. This amount is far in excess of the facts. Evidence to this effect is supplied by the position of the ramparts with reference to the shores. The writer's observations show that in most cases permanent ramparts are found in close proximity to high water shore-line of the lake. Thus, it seems evident that only the larger rises in temperature are effective. Here again we may suggest that the compressibility of the ice and melting due to compression may be

the factors that render the diurnal changes in temperature ineffective.

A snow covering more or less effectively blankets the ice and prevents or retards the transmission of air temperatures to it. The occurrence of a snow covering depends on the amount and kind (wet or dry) of snow and also on the wind velocities during and subsequent to the precipitation.

From the mechanical side it is necessary that the ice be of sufficient strength to act as a strut against the stresses imposed upon it. As stated by Hobbs (3), the factors are the flatness of the surface, the homogeneity of the ice, and the thickness of the ice in relation to its length.

As to flatness of surface, lake ice free from snow tends to deform with changes in temperature, as has been shown above. This is effective during expansion when the ice-sheet tends to become convex upward and makes the ice less able to transmit the horizontal stresses, necessitating thicker ice than would otherwise be the case. The homogeneity of the ice is greatly interrupted by the numerous healed cracks which are sometimes crushed by subsequent expansion, according to Tyrrell (8).

The thickness of the ice in relation to its length is important, since the competency of a strut varies inversely as its length. Not only are there lakes of various sizes (length of strut) in a given locality, but also there are important variations in the thickness of the ice formed during different winters. We may have, then, lakes so small that the expansion results in a shove on the shores, since the thickness of the ice is always great enough to cause it to serve as a strut. In such cases the amount of expansion is often small and the results insignificant. On the other hand there are lakes so large that the ice is never thick enough to serve as a strut, but buckles into pressure ridges which usually occur in the same locations each year. An intermediate class are those upon which the ice attains sufficient thickness only during winters when meteorological conditions are especially favorable. Upon such lakes expansion is most important.

However, the size of the lake (length of strut) seems to be the most important of the mechanical factors and there is a limit in

size of lake upon which a competent ice layer is formed under given climatic conditions. This limit, as stated by Hobbs (3), is not much over one and one-half miles and is certainly under four miles for climates such as southern Michigan. The writer's observations indicate that expansion seldom, if ever, occurs in an ice-sheet of more than two miles in extent. In considering the size of lake the smallest diameter must be taken. Thus, on long, narrow lakes the ice is incompetent for the long diameter and buckles in lines which run across the lake between salient points, while along the shorter diameter the ice pushes on the shores. The expansion in this case is radial from the center of each block and not necessarily normal to the shores. Likewise the ice may expand in a more or less enclosed indentation, but not on the main lake.

The essentials of this theory are: Ice contracts with lowering temperatures and the contraction is accommodated by tension cracks in the upper part of the ice and not by pulling away from the shores; these cracks are healed by freezing and the ice completely covers the lake; the average density of the ice increases as the temperature is lowered; with rising temperatures the ice expands; the result of the expansion is either a buckling of the ice or a shoreward extension of its edge, which remains until the ice melts.

The necessary conditions are: A lake not too large to form a competent ice layer; a winter season of sufficiently low temperature to form a competent ice layer; large and relatively rapid cyclonic changes in temperature during the winter and the absence of a snow blanket, in order that the temperatures may be communicated to the ice. All these factors vary, therefore expansion takes place only under a favorable combination of the climatic factors on the smaller lakes.

Another method of ice-shove was advocated by Tyrrell (8), as a result of his observations on Canadian lakes which lie well to the north of those studied by the writers cited. This we may call the ice-jam method. It has also been advocated independently by Taylor (9, pp. 337–338) to account for ramparts found on the shores of glacial Lake Maumee, although not

worked out as to detail. The essentials of Tyrrell's theory follow.

Ice on lakes in regions of heavy snowfall increases primarily from the top rather than from below. The snow forms an insulating covering which prevents the air temperatures from being rapidly transmitted to the ice and changes in volume do not occur. At times, however, the snowfall is light and the temperatures are transmitted to the ice. With a drop in temperature cracks and open lanes of water are formed and these are promptly frozen over. But with subsequent rise in temperature the ice does not expand farther than to close up these lanes by crushing the new ice and "the shores remain undisturbed all winter." According to Tyrrell, the horizontal expansion which is not relieved by crushing in the healed cracks and lanes is expended in a vertical direction and has very little effect in increasing the thickness of the ice.

Other ways in which this expansion may be accommodated without shove on the shore have been discussed above, but another factor is present in this case which may have some importance. The load of snow which ice may carry without downward deformation is limited, especially if it falls soon after the ice is formed. Tyrrell states that one inch of ice will carry only five eighths of an inch of snow, and a three-inch ice sheet but two and one-half inches of snow. If the superjacent snow is proportionally greater than the amounts stated, the ice will sag and water will rise through the openings and wet the snow, thus increasing the load. It is possible, then, that the expansion may result merely in a greater downward deformation of the ice sheet, or that the ice formed from the freezing of this slush is weaker than normal ice and will crush under the compression to which it is subjected.

In the spring the ice melts first near the shores because of the relatively rapid heating of the earthy material of the shore and the shallow bottom. An open lane of water is formed which is further widened by a rise in lake level from the water added by the melting snow of the surrounding slopes. If strong winds develop before the ice becomes rotten, the ice is blown about

from side to side by the varying winds and pushes on the shores "with almost irresistible force." The direction of the shove is related to that of the winds and may vary along any shore even during a jam, if the winds shift considerably. The force of the push depends on the firmness and momentum of the ice, the latter being determined by the velocity and duration of the wind, the weight of the ice and to some extent the distance through which the ice is free to move.

Since strong surface winds in latitudes where climate suitable for ice action prevails are largely controlled by cyclonic disturbances, all shores of a lake may be affected by ice-jams, but not to the same degree. Strong winds occur in the cyclonic or low pressure areas whose centers move eastward over North America, passing in the vicinity of the Great Lakes for the most part. The passage of one of these storms is accompanied by a shifting of the winds and an increase in velocity, which usually reaches its maximum when the air is moving directly to the low from the high adjacent on the west, winds with westerly component. The shifting of the winds is through the southerly half of the circle if the center of the low passes to the north and through the north when the path lies south of a locality. There is, then, at first a crowding of the ice to the northwest or southwest parts of the lake, depending on whether the center of the storm passes to the south or north. This crowding is of moderate intensity because of the generally low velocities of the easterly winds, but serves to open a wide lane of water on the east side. This wide lane of water, together with the increased velocity as the wind shifts to the west, tends to give increased push on the northeast or southeast shores. In southern Michigan most of the storm-centers pass to the north, giving the strongest push on the northeast shore. Occasionally a storm-center passes directly over this region, which intensifies the push on the east shores. Farther north this condition should be reversed and the southeast shores should be most affected. Weather conditions, however, are extremely variable and it should be evident that all shores of a lake may be affected by jams, but not to the same degree.

Ice-jams are not effective on small lakes because of the in-

ferior amount of ice, but should increase in power with the size of the lake within limits, the upper limit depending more or less upon whether the lake completely freezes. This does not preclude the possibility of ice-jams on lakes, such as the Great Lakes, which do not completely freeze ordinarily, but their effects are removed subsequently by the powerful wave action. Another factor that may or may not increase the effectiveness of jams is the piling up of the ice at its margin as a result of the buffeting to and fro. This increases the depth to which the ice extends and, therefore, the amount of material available for transport, but also tends to prevent the jam from reaching the beach.

Thus, there are two ways in which ice shoves on the shores of lakes. Each is dependent on a favorable combination of weather conditions and, therefore, may or may not be active during any winter. Of the two the ice-jam has a much wider application both as to size of lake and climatic variation and may coöperate with expansion on some lakes during the same winter. As to the force exerted in each case, the writer has nothing to offer except that both are effective from a physiographic standpoint.

EFFECTS

It is obvious that, whatever the cause of the ice-push, the effects produced are in part dependent on shore conditions, and in this are included the material at hand and the topography of the shore. The work of physiographic importance is the shoreward transportation of earthy material which may be frozen in the ice or pushed in front of the ice edge. The amount transferred depends on the area swept by the ice, the number of times the ice has advanced and the amount of available material. The first and second of these conditions need no discussion. Under available material must be considered the consolidation, and the size and quantity of particles. In general, lack of consolidation is necessary but some consolidated rocks, as the term is generally used, where closely fractured, e.g. thinly bedded limestones, are moved by the ice as at Indian Lake near Manistique, Michigan.

Coarse material is readily transported while fine material, such as sand, allows the ice to pass over it with little or no disturbance. Usually, however, materials of all sizes are mixed and much fine material, which would otherwise not be moved, is carried along with the coarse. Exceptions are to be noted in the case of fine material which is bound by vegetation. Excellent examples of this were noted by the writer on the shores of Torchlight and Crystal lakes in Antrim and Benzie counties, Michigan. At the north end of Torchlight Lake a sand rampart was noted which ran parallel to the shore just in front of a row of poplars. This rampart plays out at each end of the row of trees. Inasmuch as it showed little effect of subsequent wave-erosion, its absence, where it was not bound by the roots of the trees, signifies that none was formed there. On Crystal Lake a small, but well-defined, rampart was noted where a strong growth of dune grass served as binder for the sand (see Fig. 6).

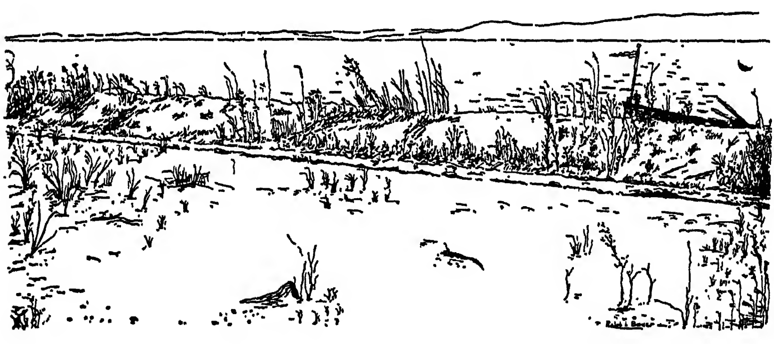


FIG. 6. Small ice rampart of sand, Crystal Lake
(Drawn from photograph)

The permanence of ramparts depends largely on the size of the constituent material and its position with reference to the shore. Sand, when bound by vegetation, is frequently pushed into ramparts only to be destroyed by waves during the following season, while coarse material may successfully withstand the beating of the waves for a long period. Obviously ramparts

formed beyond the reach of the waves will develop faster and persist longer than those within the range of wave action.

The quantity of available material refers to the amount of coarse material. This material will sooner or later be exhausted unless the lake level is lowered, in which case fresh areas are brought into the zone of ice action.

The topography of the shores is of great importance. The amount of forward movement possible varies inversely as the steepness of the shores. At the foot of steep cliffs the movement is least, but some is always possible even in expansion because this process works during periods of low water. In such cases the material is eventually forced into the bank, giving a paved or mosaic effect, or is left at the foot of the cliff where wave action removes the finer material and leaves a line of boulders as shown in Plate IX, Figure 1. Low cliffs are sometimes overridden by the ice and the brow is pushed over into a rampart that is well beyond the reach of the waves. On sloping shores more ice movement is possible and ramparts are developed, provided material is available. The proviso is necessary because many flat shores are developed by wave and current action and the material is fine.

Ice ramparts have been described and classified by Braun (10) and Buckley (1). According to the latter, they are as follows: ridges formed on shelving shores, those formed on a low cliff, and folds formed on low marshy shores. The first two may be considered as relatively permanent, but the third type disappears when the frozen vegetal mat thaws. Of the permanent ramparts those formed on shelving shores are much more common and may be considered typical.

Such ridges stand above the surrounding land both fore and back and are somewhat irregular in continuity, height and slope. They increase in size with each advance of the ice until the available material is exhausted, at which time they have reached a maximum development, or until the rigidity of the rampart exceeds that of the ice. When the latter condition prevails, the expanding ice will buckle and ice-jams will shear over the top of the rampart. Since some movement is possible, each advance

leaves a deposit in front of that left by the preceding advance, forming a terrace composed of a series of typical ridges, known as an ice-push terrace. According to Fenneman (11, p. 34), a gradually lowering lake level is necessary for the formation of these terraces by expanding ice. One other topographic form which results from ice-shove has been described by Fenneman (11, p. 33) as follows: "Ridges are frequently met with which in position and horizontal form would be called spits, but whose composition is of bowlders and thoroughly unassorted material. Such ridges may generally be accounted for by the agency of ice, pushing up the materials of a shoal bottom which a subsidence of the water level has brought within the reach of the ice. Similar forms were observed by the writer on one lake and will be discussed later."

Thus far the writer has attempted to state somewhat fully the principles involved in the two theories of ice-shove and to discuss the effects. No attempt has been made to differentiate between the effects of the two processes and purposely so. All the topographic forms, with the possible exception of boulder spits, which result from ice action, may be accounted for by either method of shove, and the writer knows of no distinctive characteristics. Of these the boulder-lined strand at the foot of cliffs is readily accounted for, since such places mark the limit of forward-moving ice of either process. The fact that the ice is often piled up at its forward edge during a jam makes the depth to which the ice will scour the bottom greater than where expansion takes place and the available material is thereby greater, giving stronger effects.

Ramparts due to expansion have been observed in the process of formation, but the same cannot be said for ice-jams. Tyrrell (8) has found well-developed ramparts back from the shore and also large boulders in the process of shoreward movement on lakes much too large for expansion, and states positively as a result of observation that expansion does not take place. In addition the paths of the boulders in some cases abruptly change direction, a fact readily explained by a shifting of the wind during a jam or successive jams, but offering difficulties when the

attempt is made to account for them by expansion. On first thought it would seem that the ice edge of jams would be irregular and that the resulting rampart would show less regular delineation than those of the expansion type, thereby giving a means of differentiation. The writer, however, was unable to find any such criteria and wishes to call attention to Plate IX, Figure 2, a view of an ice-jam on Crystal Lake, Benzie Co., Michigan, which shows a remarkable (to the writer at least) regularity of the edge. Other photographs of this same jam and of jams on other lakes, not here reproduced, show less regular ice edges, but sufficiently so to form ramparts when it is considered that the rampart is an indication of the average position of the ice front of numerous jams, and that a strong rampart may offer considerable resistance to the movement of the ice.

As regards ice-push terraces, it is readily seen that successive advances of the ice may form a succession of the ridges, provided the available material be sufficient. If they are formed by expansion, it is generally necessary to assume with Fenneman a gradual depression of the water level of the lake, which would bring the material of new areas of the bottom of the lake into the zone of ice action and also progressively decrease the outer limit of ice movement for each advance. Such a terrace might be formed if the expansion during successive seasons were progressively smaller, but would be destroyed on being overridden by a subsequent large expansion. In case it is formed by ice-jams, no lowering of water level is necessary. The available material is greater to start with — see discussion of boulder-lined strand above — and may be added to by the along-shore movement of coarse material by floating blocks of ice driven by waves and currents. Successive jams force the material into a series of ridges, and subsequent jams of great force will pass over the terrace by shearing rather than scour. Such an ice-push terrace is shown in Plate X, Figure 1, a view of Poplar Point on Lake Athabaska, Canada. This lake is one of large dimensions in a region of heavy snowfall where expansion does not take place, according to Tyrrell's observations.

The sufficiency of simple ice expansion, that is normal to the

shore, for the formation of boulder spits is doubtful, but may be a contributing factor where a normal spit continues along the main shore-line of the lake. Under such circumstances the ice may push against the spit, but suitable material is unlikely inasmuch as it is largely current-born, that is, sand. Only two of these forms were seen by the writer, both on Long Lake, Alpeña Co., Michigan. One, shown in Plate X, Figure 2, has characteristics resembling a cuspate foreland, except that the material is angular and much too large to have been moved by waves and currents on this lake. It extends abruptly out into the lake and is clearly formed by deposition. Obviously expansion normal to the shore cannot have formed this feature. The suggested explanation is that this point on the shore is the location of one end of a pressure ridge which extends across the lake. The expansion is then towards the pressure ridge and, therefore, towards the sides of the cuspate foreland. This resembles the holm of Gustafsson (12, pp. 145–178).

Another similar form, which occurs on Long Lake also, is shown in Plate XI, Figure 1. The main body of the lake is to the left in the picture and it will be noted that the surface material of the spit is coarse, the shape serpentine, presenting a convex curvature to the lake near its attachment to the shore. Much of the material below water is sand, the slopes are characteristic of normal spits and its position is across the mouth of an indentation, although the form leaves the shore at an abrupt angle. This spit, then, has characteristics which indicate both ice and current action. It is possible to explain this form in the same manner as that discussed in the preceding paragraph, but there is also the possibility of ice-jams having been effective. Both methods of ice-shove are active on this lake, according to the testimony of the inhabitants of the region. The jams are especially severe on the northeast shore, sometimes reaching a height of ten feet. Ramparts are found at favorable locations on all shores, but are higher and more continuous on the northeastern shore. This may be due in part to more favorable shore conditions, but other evidence indicates that jams are especially effective on this shore. In Plate XI, Figure 2, is reproduced

a photograph of one of a number of boulders which have been pushed shoreward by the ice on this lake.

Such boulders were found in three localities, all on the northeastern shore, and the direction of their paths, which were very clear, was found to deviate but slightly from N. 50 E., irrespective of the direction of the shore-line. Near the north end this varies considerably from the normal to the shore-line, which would be the direction of ice expansion, and it is evident that all were moved by an ice-jam, and perhaps by the same jam, although the lake is well within the limits for expansion.

The following statement of conclusions may be made: (1) Since many of the largest ramparts noted on Michigan lakes were found on lakes which are too large for expansion to be effective, e. g., Indian Lake, Schoolcraft Co., Pine Lake, near Charlevoix (Nipissing shore), Higgins and Houghton lakes, Roscommon Co., and Hubbard Lake in Alcona Co., ice-jams push on the shores of inland lakes in climates such as that of Michigan and, therefore, both ice-jams and expansion are effective; (2) Similar topographic forms result from the work of either process; (3) Both methods may be effective on the same lake, provided it does not exceed two miles in shortest dimension; (4) The ice-jam, on account of its greater range as to climate and size of lake, is of wider occurrence; (5) In climates similar to that of Michigan the ice-jam appears to be the more effective; (6) In the cases of some of the lakes the evidence points clearly to a stronger push on the northeastern shore, indicating cyclonic control of ice-jams.

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PLATES IX–XI

PLATE IX

FIG. 1. Raised Boulder Strand, Torchlight Lake

(Photograph by Donald Gibbs)

FIG. 2. Ice-Jam, Crystal Lake

PLATE X

(Courtesy of the Department of Mines, Geological Survey)

Fig. 1. Ice-Push Terrace, Athabasca

Fig. 2. Ice-formed Cuspate Foreland, Alpena County

PLATE XI

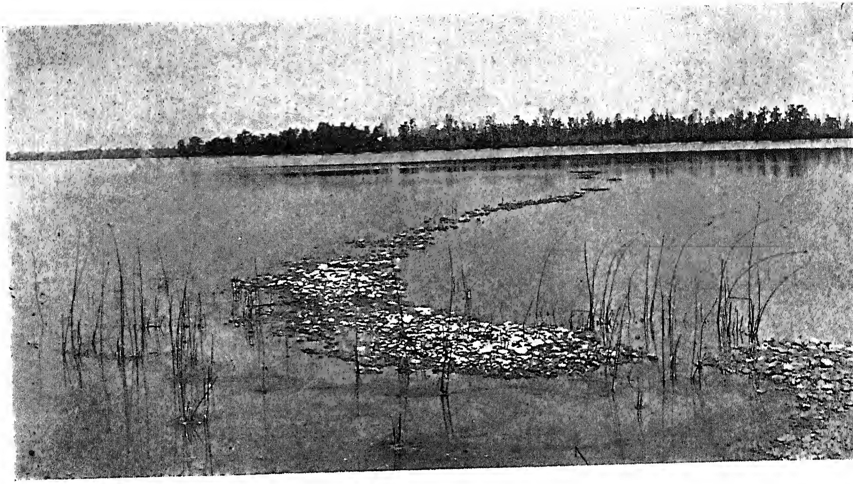

FIG. 1. Ice-formed Spit, Long Lake, Alpena County

FIG. 2. Boulder pushed on Shore by an Ice-Jam, Long Lake, Alpena County

This boulder will travel up the beach in stages and eventually become a part of the rampart

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THE CREELSBORO NATURAL BRIDGE

IRVING D. SCOTT AND RALPH L. BELKNAP

IN CONNECTION with the work of the University of Michigan Summer Camp for Geologists and Geographers, there has been brought to the attention of the authors an unusual case of stream-diversion which resulted in the formation of a natural bridge. This bridge, known as the Creelsboro Bridge, is located in a narrow ridge which separates the Cumberland River from one of its tributaries, Miller Creek, or, as more commonly called, Jim's Creek. The bridge itself is about four miles down-stream from the town of Creelsboro, which in turn is located in southwestern Russel County, Kentucky.

The geologists who have worked in this area, as well as those who have made a special study of natural bridges, have made but few references to the Creelsboro Bridge. In the literature on this subject only two references to this bridge have been found. Cleland (1), without citing any literature, has referred to it as an example of the type of bridge formed by lateral planation of a stream and its tributary working from opposite sides of a narrow ridge. Miller (2) has accepted this explanation of its origin and adds further that "the rock formation pierced in the forming of the bridge or tunnel is Richmond limestone of Cincinnatian age." Inasmuch as this statement of the origin has been questioned, the authors, in the summer of 1925, availed themselves of the opportunity of making a more careful and detailed investigation of this bridge than had previously been made. The data and information, and the conclusions reached as a result of this study, are believed to be of such importance as to warrant their presentation.

The introduction to this discussion may well include a definition and brief classification of natural bridges. Since this has

been so well presented by Cleland, attention is again called to the first reference of this paper.

Natural bridges are defined as arches spanning valleys of erosion. Since in the case of the Creelsboro Bridge it is a ridge between two valleys that is pierced, it might at first seem somewhat inconsistent with this definition to apply the term bridge to this particular arch. Since, however, the arch spans the present channel of Jim's Creek, the term bridge can quite properly be applied.

Natural bridges have been classified as follows by Cleland according to their manner of formation:

A. Bridges formed by deposition;
B. Bridges formed by gravity;
C. Bridges initiated by wave action;
D. Bridges initiated by solution;
E. Bridges initiated by stream-erosion.

It will be noticed that unless consideration is given to the possibility of wind action in the formation of bridges this classification is quite complete.

It is also evident, after a brief study of the bridges that have been described, that the last two causes are by far the most important in accounting for the formation of existing natural bridges.

Cleland has made three subclasses of the bridges initiated by solution. In the first group are included those which are explained so commonly as being due to the combined action of subterranean and subaërial erosion. This is the most frequently used explanation of natural bridges. In classifying bridges, however, it is found that there are only a surprisingly small number that can be included in this group. It is, then, the most common explanation, but the bridges to which it can be applied are actually of rare occurrence.

The second group of bridges due to solution includes those which are formed primarily by seepage. The Virginia Natural Bridge and the North Adams Marble Bridge are both well-known examples of this type. In this case the water seeps from the bed of a stream down a joint plane to a bedding plane, then

along the bedding plane to the surface — usually in the face of, or beneath, a water-fall, or in a rapids.

In the third group of bridges due to solution are included those which owe their origin to the partial caving in of a superficial tunnel. Inasmuch as there is no indication of this action at Creelsboro, it will not be discussed in this paper.

In general it can be said that bridges formed by solution occur very frequently, but are usually quite small. They are found in a region which has a well-developed joint-system and well-defined bedding planes.

Of the bridges initiated by stream-erosion, seven different subclasses are given. Of these the only type considered in this paper is the one resulting in the perforation of the neck of an incised meander. This is the type illustrated by the great sandstone bridges of San Juan County, Utah, a type perhaps relatively less important quantitatively, but including some of the largest bridges yet described.

Bridges formed by this process possess several important characteristics. First of all the bridge is located in the narrowest part of the meander where the two meanders were formerly back to back. There is also a large amount of undercutting near the base, resulting in the formation of overhanging cliffs. Usually the two sides of the bridge, the ends of the piers or abutments, are buttressed or planed off so that they point in toward the center of the opening; if not, the line through the center of the bridge or tunnel perpendicular to the span is nearly perpendicular to each of the streams forming it.

A modification of this method of forming the opening would be the perforation of a ridge between a tributary and main stream, by erosion where two meanders were back to back. This modification referred to as lateral planation is given by Cleland and Miller in accounting for the Creelsboro bridge.

Facing the bridge from the Cumberland side as shown in Figure 7, one is reminded of a massive skew bridge with the ends of the abutments parallel to the Cumberland and its axis almost coincident with the abandoned channel of Miller Creek below the bridge. The opening of the bridge varies in height

from 15 feet on the north side to 40 feet on the south side. It has a span of 75 feet while the dimension that should be its width, the length of the tunnel, is about 100 feet, somewhat greater than the span. The floor, while quite uneven, is about 20 feet higher than the level of the Cumberland River on the river side and rises to an elevation of over 40 feet above river level on the opposite side. In fact the bottom of Jim's Creek is about 30 feet above the normal summer level of the Cumberland.

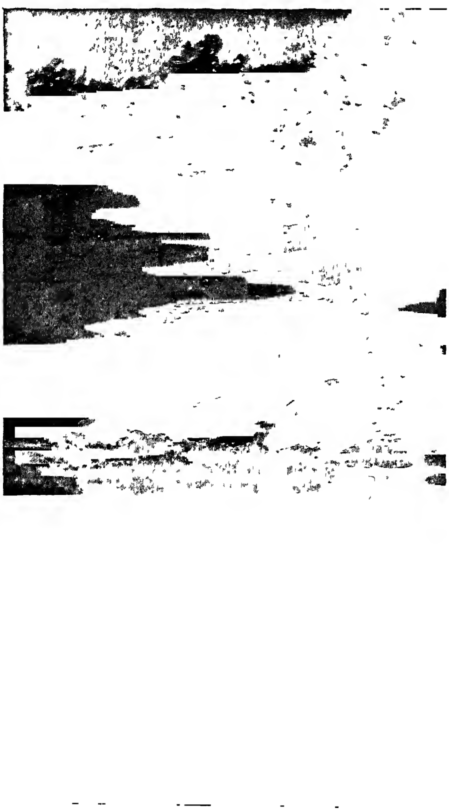


Fig. 7. Creelsboro bridge from river side

The two pictures, Figures 7 and 8, may give a more definite impression of the appearance of the bridge, particularly the condition of the faces of the cliffs. It will also be noticed from these pictures that the thickness of the rock above the opening is greater than the height of the opening. It varies greatly, but is not less than fifty feet at any point. In addition it is also observed in Figure 7 that the lowest part of the ridge is not over the bridge, but to the right, that is, on the up-stream side. This of course marks, as well, the narrowest part of the ridge separating the two streams. It is, then, the place where the bridge would normally be located if it had been formed by lateral planation alone.

The beds pierced in the formation of the bridge are rather heavy, massive, siliceous gray limestone shaly in places, usually quite fossiliferous, showing no effect of solution, and characterized by the absence of, rather than the presence of, joints.

These beds are the ones referred to by Miller as being of Richmond age. Although the authors were not interested in the stratigraphic section of the bridge, an important fact in this connection has been brought to their attention. Believing some information concerning the possible origin of the bridges could be obtained from descriptions of the physical and chemical

FIG. 8. Bridge from Jim's Creek side

characteristics of the Richmond limestone, they studied several references.

The results of this study were of no importance except to call attention to some work done by Professor G. M. Ehlers and Mr. C. F. Deiss, of the University of Michigan, who had been studying the fossils collected particularly from the beds exposed in the bridge-section. As a result of their study, as yet unpublished, it was found that the bridge was in a lower geological horizon than the one in which it had previously been supposed

to be located, that is, the fossils collected from the bridge-section were those of Maysville, rather than of Richmond, age. The Richmond formation would then be represented, if at all, by some of the beds near the upper part of the arch over the opening.

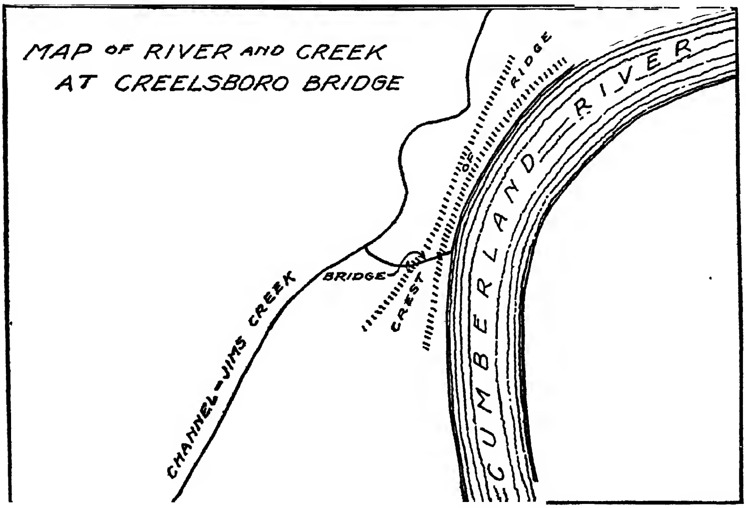
In general the surfaces exposed, while showing no indications of solution, are quite smooth. This is particularly true on the creek side of the arch where the surface conditions lead one to conclude that weathering and erosion are taking place very slowly, somewhat in contrast with the conditions on the opposite face.

Although there are indications of lateral planation by the Cumberland on the river side of the bridge, a more important effect is that due to weathering. The cliff on this side is faced with small but innumerable blocks of rock, which have been loosened by the action of weathering. Here, even though the Cumberland is cutting into the cliff, weathering is going on even a little faster, so that the cliff, rather than overhanging, is sloping in toward the crest at such a rate as to enable one to climb up at least twenty-five feet above the floor of the bridge, where further progress is blocked more by the loose material lining the face of the cliff, than by the verticality of the wall. Above this zone, however, the face of the cliff does become vertical with an occasional narrow overhanging ledge at the top.

Map 4 shows a part of a traverse which was run from the bridge down the old channel of Jim's Creek to the river, back up the river to a point above the bridge where the ridge was crossed and the traverse closed by running down the creek bed to the starting point. One of the significant things noticed in the diagram is that the bridge is located not at the narrowest point in the ridge, the logical location if lateral planation is the cause of the bridge, but some distance down-stream from this point.

From the data presented so far the authors have concluded that the opening is actually too much of a tunnel as it has been called by Miller, that is, too long and narrow to be formed by lateral planation. This conclusion is supported by the following facts: First, the axis through this tunnel is not perpendicular to

the axes of the streams forming it, but is more nearly parallel to the channel of Miller Creek on the down-stream side and makes an obtuse angle with the Cumberland on the up-stream side. Secondly, indications of lateral planation are not found on the Miller Creek side of the bridge. Although lateral planation is active on the Cumberland side, it has been so slow that practically no undercutting has resulted, weathering having kept pace with it. Last and most important of all is the fact that the



MAP 4

bridge is located down-stream from the narrowest and lowest point in the ridge. Since, then, lateral planation does not appear to have been the cause of the formation of the bridge, some other explanation must be found.

Since the bridge is located in a ridge made up almost entirely of limestone, solution would be the next explanation to suggest itself. Because of the entire absence of any indication of solution in the bridge-section, the rocks being quite insoluble, and because of the almost complete absence of joints, it has previously

been thought that solution was not responsible for the formation of the bridge.

A careful investigation of the rocks in the vicinity of the ridge resulted in the discovery on the Cumberland side of the bridge of two particularly interesting beds that had not been noticed in the bridge-section, the beds being slightly lower than the level of the floor. These beds were not more than a foot thick, of a blue limestone only slightly siliceous, showing a considerable amount of solution on the under side, particularly along a few of the innumerable incipient joints. A photograph,

FIG. 9. Solution channels along the *under* surface of a bed of the soluble blue limestone

Figure 9, shows the condition of the *under* surface of one of these layers.

The discovery of these beds in their present condition points, it is believed, to the proper explanation of the formation of this bridge. The conclusions drawn in this regard will now be presented.

The fact should be emphasized that the present condition of the bridge is not due to one factor or process alone. It is difficult even to select the predominate process that is responsible for its formation and development. Not to make a definite attempt to

do this, it is believed that the following explanation not only accounts for the formation of the bridge but indicates in the proper time-order the processes that have been chiefly responsible for it.

The bridge was initiated by solution. Water seeping downward from the bed of Jim's Creek, which is thirty feet above the normal level of the Cumberland, came to the bedding planes between the soluble blue limestone and the underlying beds, where it moved laterally, probably along the incipient joints, until it came to the surface on the Cumberland side of the ridge. It has been suggested that at this initial stage the water seeped down from the bed of the creek along a joint plane, and that the location of the plane at this point thus accounts for the location of the bridge.

The opening or channel thus initiated by solution was gradually enlarged by this process primarily along the upper surface until it allowed a more rapid movement of the water. It was then enlarged by stream-erosion, corrosion and corrasion. This would represent a second stage in its development.

At the present time the opening is being enlarged by weathering and by stream-erosion, the latter being particularly effective when the flood waters of the Cumberland rush through into the almost abandoned channel of the creek. While this action is enlarging the bridge-opening, weathering, assisted by the lateral planation of the Cumberland, is wearing away the Cumberland face of the cliff, thus decreasing the width of the bridge.

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EVIDENCE OF RECURRENT DEPRESSION AND RESILIENCE IN THE REGION OF THE GREAT LAKES

FRANK BURSLEY TAYLOR

ON THE basis of present knowledge one seems fully justified in saying that nothing within the realm of Pleistocene geology is more clearly established than the depression of the land during the growth of the Wisconsin ice-sheet in the region of the Great Lakes, with its subsequent resilience during and after the glacial retreat. It seems impossible to assign this movement of the land to any other cause than the weight of the ice, and this is the generally accepted explanation. This is assumed to be true, and it is the object of this paper to point out certain suggestive facts, and also some interesting conclusions and corollaries that follow.

It is admitted that there is not much direct evidence of recurrent depression and resilience, but this lack is largely made up by the clearness and power of certain lines of indirect evidence. In the case of the Wisconsin ice-sheet, by far the greater part of the facts upon which we rely for our understanding of the cause of the tilting movement of the land relates to the movement of resilience. The phenomena of progressing depression under the growing ice-weight were not openly recorded, and are now hard to find and interpret. But evidence which proves the differential uplifting of the land during and after the retreat of the last ice-sheet is recorded in great profusion in the uplifted and tilted shore-lines of the temporary glacial lakes which formed in front of the ice. From the first relatively small glacial Lake Maumee in the Erie basin, the waters fell to successively lower levels as the receding ice uncovered new and lower outlets farther north.

At the same time, the uplifting and tilting of the land in the north raised some of these new outlets to such altitudes that the overflow returned to previously abandoned outlets at the south. Thus, the location of outlets was changed both by the retreat of the ice-sheet and by the tilting of the land, and the interplay of these changes concurrently with the lowering of lake levels and the tilting of the abandoned beaches has built up a record which shows a remarkably close relation between resilience of the land and the retreat of the ice-sheet. A considerable part of this complex history is recorded in the story of Niagara Falls and its gorge.[1]

The story revealed by these complex changes leaves no possible doubt, as it seems to the writer, that the uprising of the land in the north is really a movement of elastic resilience following the removal of the ice-weight. If this be true — if the movement of resilience was not due to any other cause — then we are bound to believe that the depression of the land was brought about and produced by the weight of the growing ice-sheet.

There is a vast store of evidence proving the existence of other drift-sheets older than the Wisconsin. These were obviously made by ice-sheets of corresponding ages, and the evidence shows that they grew to be as extensive as the Wisconsin ice-sheet, some of them perhaps slightly more extensive. If depression and resilience of the land were an inseparable physical accompaniment of the Wisconsin ice-sheet, how can we doubt that they occurred also in connection with the Illinoian, the Kansan and the pre-Kansan or Jerseyan ice-sheets? Indeed, we should need special evidence to prove that it failed to occur in connection with any ice-sheet of continental extent that ever existed on the earth. In the writer's opinion, we are forced to

[1] The lake history as thus far worked out, is presented in considerable detail in *Monograph No. 53, U. S. Geological Survey*, by Frank Leverett and Frank B. Taylor, 1915. The history of Niagara Falls and its relation to the Great Lakes history are discussed in the *Niagara Folio, U. S. Geological Survey*, Folio No. 190, by E. M. Kindle and Frank B. Taylor, 1913. The relation of a part of the Niagara gorge to the Great Lakes history is also discussed in another paper in this volume entitled "The Present and Recent Rate of Land Tilting in the Region of the Great Lakes."

believe that this phenomenon was associated with every one of the great ice-sheets.

We have before our minds, then, an imaginary picture of four successive ice-sheets, each one producing a slow depression of the land in the Great Lakes region as the glacier grew, followed each time by a slow resilience during and after the glacial retreat. Perhaps there is yet some uncertainty as to the exact physical process by which the earth's crust yields and becomes depressed under the ice-weight, but it appears to be simple elastic yielding in a rigid body. If this be true, then the movement of resilience is in all probability simply the elastic rebound or recovery following the removal of the ice-weight. If the elastic distortion under the ice-weight is substantially perfect, with no loss from movements which pass beyond the capacity of the crust for elastic yielding, then resilience may be equally perfect.

This would mean that whatever the altitude and attitude of the surface of the Great Lakes region may have been before the beginning of the growth of a given ice-sheet, complete resilience, such that all of the elastic stress produced by the ice-weight had disappeared, would bring the surface of the Great Lakes region back to exactly the same altitude and attitude that it had before the ice-sheet began to grow. It is perhaps hard to think of elastic movements in the earth's crust as being so perfect, but if they are slow enough and do not anywhere exceed the elastic limit so as to produce faults or plastic changes of form that become set and lose their tendency to return to their original form, they may show remarkable perfection in recovery; that is, in the resilience of the region previously depressed.

Since the time when the Wisconsin ice-sheet and the accompanying lake waters uncovered the Niagara region, the cataract has cut out of the solid rocky strata the gorge or canyon in which the river now flows from the Horseshoe Falls to the escarpment south of Lewiston, New York, a distance of about seven miles. The factors which determined the course of overflow from the upper lakes, and caused the Niagara River to be placed where it is, instead of flowing southward through Chicago to the Mississippi, or eastward at some point in Canada, are the main

topographic features of the region — the lake basins and the barriers between them and around them — and the relation of these to the level of the waters in the lakes.

If the Illinoian ice-sheet produced a great depression of the lake region substantially equal in amount and distribution to that produced by the Wisconsin ice-sheet, and if a similar near-perfect resilience followed during and after its retreat, it is not inconceivable that in the restored drainage the overflow of the lakes may have followed almost the same path as that of the present Niagara River. If this river carried the whole discharge of the upper lakes, as the writer believes it did, it had the same volume as the present river, and the geological conditions being the same, it would have formed a vertical cataract at the escarpment and begun the making of a gorge the same as did the present river. But the history is not by any means so simple as this statement might seem to imply.

THE EVIDENCE: SUCCESSIVE NIAGARA GORGES

When the present river had made about half of its gorge from Lewiston up, it came to a place where it encountered only loose, soft sediments, a great cavity in the rock filled only with clay, sand and boulders, all the rocky strata having been removed at an earlier time. The modern river cleared out the loose detritus very quickly, and the place is now known as the Whirlpool.[2]

When the modern river had cleared the Whirlpool basin, it met solid rock walls all around, except on the northwest side. Here the wall is composed of the same loose material extending far below the water-level. In short, the Whirlpool basin is the southeast end of a great buried gorge which extends two miles northwest to the escarpment south of St. Davids, and is known as the St. Davids gorge. Until the modern river opened it, this ancient gorge was wholly buried under glacial deposits of

[2] The characteristics of this part of the gorge are given in some detail in the *Niagara Folio*, page 17, columns 1 and 2, including especially Figure 7, and on the large scale gorge map. The general relations of the features of this area are shown on the accompanying sketch map, Figure 10.

Wisconsin age, and could have been found only by borings and by the break in the rock ledges south of St. Davids.

The top width in rock of the ancient gorge is about the same as the modern full-volume gorge from Wintergreen Flat to Niagara University, and at the American Falls. It might be expected from the long period of weathering to which it was probably exposed before it was filled that it would be considerably wider, but the difference is small. Although glacial striae were found in Bowman's ravine on the west wall ninety feet below the top, glacial abrasion seems scarcely perceptible in amount. As revealed at the Whirlpool and near St. Davids, all the characteristics of the ancient gorge indicate that it was made by a vertical cataract of great volume.[3]

It is believed, therefore, that the buried St. Davids gorge was made by the cataract of an earlier great river, in reality by an Illinoian Niagara which did its work probably after the recession of the Illinoian ice-sheet and late in the Illinoian resilience. This gorge was later overridden and filled with detritus by the advancing Wisconsin ice-sheet. The fact that there are only two miles of the St. Davids gorge as against seven

[3] Space forbids a more detailed description of the features around the Whirlpool or an adequate discussion of their significance. The key to the history of the Whirlpool area is revealed in the origin and history of the Eddy basin. This is a very short but wide and deep-gorge section next above the Whirlpool, from which it is separated by a well-defined reef and rapids. (See *Niagara Folio,* Figure 14, page 21. The history of its development is shown more fully in Figure 7, page 17.) The features show conclusively that the Eddy basin was made by the modern cataract with full volume plunging from a solid ledge, thus disproving the suggestion of Pohlman, Grabau and others that the St. Davids gorge, the Eddy basin and the gorge of the whirlpool rapids are simply the weathered ravine of a small preglacial river uncovered, scoured out and now occupied by the Niagara River. The more recent idea that the St. Davids gorge may have been made by a small cataract carrying only the discharge of Lake Erie (15 per cent of the full volume), and later enlarged by weathering, is hardly more satisfactory, for, so far as now visible, the amount of cliff recession caused by weathering is no greater in the ancient gorge than in the modern gorge below the Whirlpool. Besides, the hard stratum of the Albion sandstone, here just above the water, is widely and deeply penetrated; whereas, in the gorge of the whirlpool rapids the cut through this stratum is notably narrow and shallow, and this section of the gorge is known for a certainty to have been made by the small-volume Erie cataract.

miles of the Wisconsin or modern gorge may possibly be due to a different distribution of outlets in the north during the earlier part of the Illinoian resilience. In the present resilience, the outlet of Lake Algonquin was on a sill of gneiss at Kirkfield, Ontario. This resisted erosion strongly. But suppose that the Illinoian analogue of this outlet had been at some point on the deep drift barrier north of Lake Ontario. As resilience progressed the outlet would be cut down, and the shift of outlet to the south, analogous to the modern shift from Kirkfield to Port Huron, might not have occurred. Then there would have been no Illinoian gorge section corresponding to our present Lower Great gorge. It would then be only late in the Illinoian resilience, when all northern outlets had been uplifted, that the four lakes would send their whole discharge to the Niagara escarpment to make a gorge. Then, too, there is only a drift barrier between Lake St. Clair and Lake Erie, so that the latter may have begun flowing north to Lake Huron as soon as an eastward outlet was opened from that lake. Slight differences in drift distribution in the Illinoian resilience may have made large differences in the Niagara and Great Lakes history.

Farther west, as shown in Figure 10, there is another significant break in the escarpment. This lies about four miles southwest of the City of St. Catherines. It is evidently an old gorge of some kind, but the features are very different from those seen at the St. Davids gorge. It is not buried, except perhaps a little at its south end. It is much wider and its slopes are more gentle and much more modified by weathering and erosion. Its portals, where it opens out toward Lake Ontario, are more subdued and rounded off. In some places very little bed rock is exposed. It extends south into the plain two or three miles, and directly south in front of it is a prominent drift hill over 200 feet high called Font hill. The St. Davids gorge lay athwart the main glacial movement, and consequently was not much affected by it, but this older gorge is nearly in line with the glacial trend. It is fully a mile wide on its floor and two miles or more at its top. It seems certain that the ice current entered it pretty strongly, and where it reached the head of the gorge,

the ice took an upward course and built the high deposit of Font hill.[4]

This depression was recognized as an ancient river valley

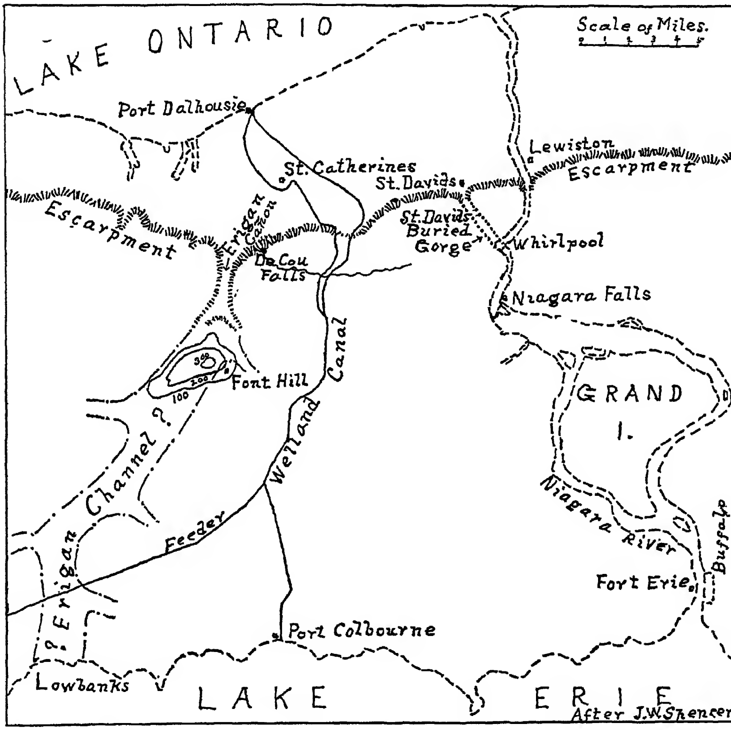

FIG. 10. Sketch map of part of the Niagara Peninsula between Lakes Erie and Ontario, showing the location of the Niagara escarpment and the three gorges described in the text

long ago, but it was probably first pictured by the late Dr. J. W. Spencer as the course of a preglacial outlet of Lake Erie, and named by him the Erigan Canyon. Spencer's views of its

[4] *Evolution of the Falls of Niagara*, by J. W. Spencer, Canadian Department of Mines, Geological Survey Branch, Ottawa, 1907. Chapter XXXVII, maps on pages 415 and 121.

relation to the lake history were entirely different from those here outlined, for he did not accept the idea of the continental glacier; he was a follower of Lyell, Selwyn and Sir Wm. Dawson.

When we recall how greatly the Kansan drift-sheet, where it is typically exposed in the west, has suffered by leaching and by subaërial erosion, and how the first trenching streams have widened their valleys until scarcely any of the original flat surface is left, we ought to be prepared to expect a great gorge made during and after the retreat of the Kansan ice-sheet to show just such extreme weathering and modification as this one does. The Erigan Canyon has only the very small Twelve-Mile Creek flowing in it now; yet in this peculiar terrane, with the heavy bed of the hard Lockport dolomite above and deep soft shales below, we seem bound to recognize that this canyon was made by a great river, and if so, it must have had a vertical cataract, like the present falls of Niagara. Except as an outlet of Lake Erie, there is no chance in this locality for a great river from the south.

If the overflow of the upper lakes during and after the retreat of the Kansan ice-sheet passed south to Lake Erie, and thence north to Lake Ontario, as does the present Niagara River, then, in the opinion of the writer, there is much reason to believe that Spencer's Erigan Canyon is the much-weathered survivor of the gorge of a Kansan Niagara. Of a possible pre-Kansan or Jerseyan Niagara gorge we know nothing, and there seems to be no place for it, unless it entered from the west through the Dundas Valley. No reason has been given for regarding the Erigan Canyon as preglacial rather than early interglacial.

Our conclusion, therefore, is that on theoretical grounds depression and resilience of the land in the Great Lakes region have occurred in connection with at least the last three of the Pleistocene ice-sheets, and probably with the first one also, and that, at least for a part of the time, the full drainage of the upper lakes was each time restored to the Niagara district, after having been temporarily taken away. Hence, looking backward in time, we have (3) the gorge of the Wisconsin Niagara (now

in the making); (2) the gorge of the Illinoian Niagara (the buried St. Davids gorge, and (1) the gorge of the Kansan Niagara (Spencer's Erigan Canyon). Back of this there is still the possibility of an earlier gorge of a pre-Kansan or Jerseyan Niagara, but of this nothing is now known.

If this interpretation of the features described is in the line of truth, it seems to throw a new light on the capacity of the earth's crust to yield by elastic distortion to a slowly accumulating weight, and on its ability to return by elastic resilience or rebound to the exact shape and position which it had before. The amount of depression north of Lake Superior and Georgian Bay was certainly not less than 1,000 feet, and the depression affected a very wide area. Within the depths reached by slow distortion under growing ice-weight, the behavior of the earth's crust certainly bespeaks the solid, more-rigid-than-steel condition set forth by the writer in recent papers on continental crust-sheet movements, and it also agrees with the "elastico-static" condition recently described by T. C. Chamberlin (*Journal of Geology,* Jan.–Feb., 1926).

From their specific gravities we know that 3,000 feet of glacier ice is equal in weight to about 1,000 feet of average crust rock. Ice-sheets come and go in a way that rock sheets do not, and they act more to protect and preserve the rock surface beneath them than to destroy it. This is why they reveal so clearly the elastic capacity of the earth's crust. Rock sheets are eroded and carried away in a manner that gives no indication of the resilience effects which they produce. The behavior of the earth's crust under the loading and unloading of ice-sheets shows what great distortions must affect much of the crust all the time. With increasing depth, resistance to distortion increases and finally, combined with rigidity, becomes adequate to support large features of topographic relief, even mountain ranges and continents.

Fort Wayne, Indiana

THE PRESENT AND RECENT RATE OF LAND-TILTING IN THE REGION OF THE GREAT LAKES

FRANK BURSLEY TAYLOR

CORRELATIVE CHAPTERS IN NIAGARA AND GREAT LAKES HISTORY

IT IS interesting to know that the Niagara and Great Lakes histories are really parts of one story, and that while the Upper Great Gorge (the newest section) was being made at Niagara, a corresponding chapter in the history of the upper lakes was being enacted, and that this chapter, like that in the gorge history, extends down to the present time. When the retreating ice-sheet opened the outlet at North Bay, Ontario, the whole discharge of the upper three lakes went eastward through the Mattawa and Ottawa valleys, leaving Niagara with only the overflow from Lake Erie, amounting to about 15 per cent of the present full volume. This condition lasted for several thousand years, and it was during this time that the so-called gorge of the Whirlpool Rapids was made at Niagara, and also the Nipissing beach in the northern part of the upper lakes. These two features are exact correlatives in time, and we may know from this that both of the processes which they represent stopped at the same time and began some new activity. As a matter of fact, the small-volume fall stopped making the gorge of the Whirlpool Rapids, and the great fall began making the Upper Great Gorge, while at the same time the waves of the upper lakes stopped making the Nipissing beach and began making the post-Nipissing beaches at lower levels.

In the upper lake region, the differential uplift of the land was either going on continuously during the time of the Nipissing Great Lakes, or else was renewed after a time of rest, so that

finally it raised the North Bay outlet to the same altitude as that at Port Huron. In this transitional phase both outlets were for a time active at once, the discharge being divided between them. But soon North Bay was raised enough to shut off all overflow at that place and that outlet went dry, the whole discharge thereafter going past Port Huron to Niagara. This, of course, stopped the making of the Gorge of the Whirlpool Rapids, brought full 100 per cent volume back to Niagara, and started the making of the Upper Great Gorge. Since that time, which was probably between 2,700 and 3,000 years ago, the great cataract has gone on steadily in the work of gorge-making down to the present day, and has made a little more than two miles of wide deep gorge.

The time factor derived from the study of the Upper Great Gorge tells us that the North Bay outlet was closed by uplift 2,700 to 3,000 years ago. If, now, we go to North Bay we see something that is almost startling, for we find that since that time North Bay has been uplifted about 102 feet. These facts furnish part of the data for determining the rate of tilting in this period before the beginning of gage readings. But before one undertakes to calculate the rate, it is necessary to consider certain other factors. In working out the history of the Great Lakes (*Monograph 53, U. S. Geological Survey,* 1915, Chapter XXII, "The Nipissing Great Lakes"), it was found that the differential uplift which caused the tilting of the land did not affect the whole area of the upper lakes. For example, if one were to start on the Nipissing beach at North Bay, Ontario, and follow it toward the south-southwest, one would find the beach descending very evenly at the rate of about 0.43 feet per mile. But as the south end of Lake Huron was approached, it would be seen that within the space of a few miles the beach ceased to descend and became perfectly horizontal, continuing in this attitude to its southern limit at Port Huron. (See Fig. 11.)

HINGE-LINES AND AREAS OF HORIZONTALITY

The line of maximum rise for the Nipissing beach runs about N. 22° E., and the isobases or lines of equal elevation run at

right angles to this or about N. 68° W. The isobase of zero marks the northern limit of horizontality and is parallel to the other isobases. This line passes through Grand Bend, Ontario,

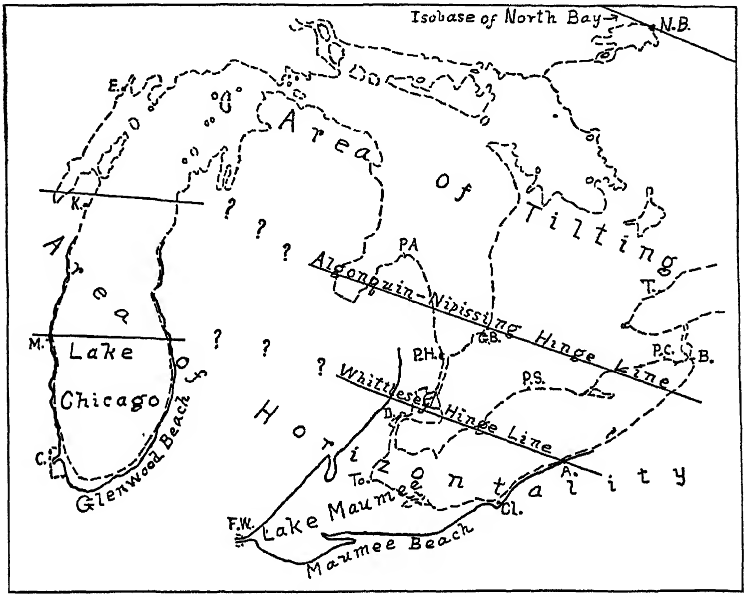

Fig. 11. Sketch map of region of Lakes Michigan, Huron and Erie and of glacial lakes Maumee and Chicago, showing earliest known position of hinge-line (Whittlesey) and the latest position (Algonquin-Nipissing), with area of tilting to the north and area of horizontality to the south. (Compare with Figure 12.) A. = Ashtabula; B. = Buffalo; C. = Chicago; Cl. = Cleveland; D. = Detroit; F.W. = Fort Wayne; G.B. = Grand Bend; K. = Kewaunee; M. = Milwaukee; N.B. = North Bay; P.A. = Port Austin; P.C. = Port Colbourne; P.H. = Port Huron; P.S. = Port Stanley; T. = Toronto; To. = Toledo.

about two miles north of Richmondville on the east shore of the thumb of Michigan and about the same distance north of Standish on the west side of Saginaw Bay. It divides the beach-plane as a whole into two parts; north of the line is the area of tilting, south of it the area of horizontality. On account

of this relation, the isobase of zero is conveniently called the *hinge-line*. In the field it is commonly easy to limit it to a belt four or five miles wide by direct observation, but by plotting many observations to the north and the south and drawing an eye-line mean through the plotted points, it may be located theoretically within a mile or less.

Using the general chart of the Northern and Northwestern Lakes (U. S. Lake Survey) as a base, and drawing the line of maximum rise from Port Huron in a direction N. 22° E., one finds that this line intersects the Nipissing hinge-line at a point about thirty-five miles north of Port Huron and meets the isobase of the northern outlet at a point about forty-seven miles west-northwest of North Bay. The distance between the hinge-line and the isobase of North Bay is about 238 miles. The tilting of the land in the post-Nipissing stage of the lakes has amounted, therefore, to 102 feet in 238 miles. This gives a rate of northward rise of nearly 0.43 feet or slightly less than six inches per mile.

If we assume that the tilting of the land went on evenly during the post-Nipissing period in the area here considered, these facts furnish the means of calculating the rate of uplift during that period, nearly all of which antedates the gage readings, but which extends down to the beginning of the present or gage-measured period in which the fluctuations of water-level in the Great Lakes have been accurately recorded on gages set by the Government for that purpose. The uplift has affected the area as though it were a great sheet of rigid inflexible material lifted up at its northern edge. (See Fig. 12.)

If we follow the method employed by Mr. Gilbert, and calculate the rate of uplift since the closing of the North Bay outlet, we find that on the assumption that the period endured 3,000 years the rate of uplift was 1.38 feet per 100 miles per century, while if the period was 2,700 years, the rate was 1.58 feet per 100 miles per century, the mean being 1.48 feet. At this point a question of great interest naturally presents itself, namely: Has the tilting of the land continued in the same direction and at the same rate down into and through the present or gage-

measured period? So far as I can see, there is every reason to believe that the tilting movement has so continued with all the attendant conditions unchanged. Let us see what light recent investigations throw on this question.

STUDIES OF LAND-TILTING IN THE LAST FIFTY YEARS

The first careful study of the records of the water gages on the Great Lakes was made by Mr. G. K. Gilbert about thirty years ago. His results are embodied in a paper entitled "Recent Earth Movement in the Great Lakes Region." [1] Mr. Gilbert

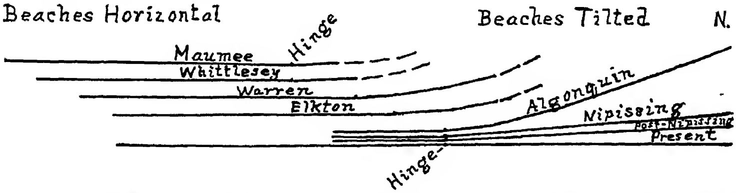

FIG. 12. Diagram showing the shifting position of the hinge-line with recession of the ice-sheet and the fall of lake level. Shows tilted attitude of shore-lines to the north and horizontal attitude to the south of each position of the hinge-line. (Not drawn to scale)

used measurements covering a period of about twenty years, from 1875 to 1895. In the Michigan-Huron area he used gage readings at two pairs of stations, Milwaukee and Escanaba, and Milwaukee and Port Austin; in Lake Erie, Cleveland and Port Colbourne; in Lake Ontario, Charlotte and Sacketts Harbor. Mr. Gilbert used the whole distance between Milwaukee and Escanaba in estimating the rate of uplift and obtained a rate of 0.43 feet per 100 miles per century, and he treated the other pairs of stations by the same method, obtaining as a mean rate 0.41 feet per 100 miles per century.

There is no question of the correctness of Mr. Gilbert's results on the data which he used, but he was somewhat unfortunate in preparing his paper a little too soon. Field-work in the study of the Great Lakes history was going on at that time,

[1] *Eighteenth Annual Report U. S. Geological Survey*, 1896–1897, pp. 596–647.

but had not yet proceeded far enough to show the existence of *hinge-lines* or isobases of zero separating areas of tilting on the north from areas of horizontality on the south. Except in the case of the oldest or Maumee beach in the Huron or Erie basin and the Glenwood beach in the Lake Michigan area, hinge-lines were found for all the ancient beaches, but the Algonquin and the Nipissing and post-Nipissing beaches converge to the same line. This hinge-line, spoken of above as passing through Grand Bend, Ontario, also crosses Lake Michigan at a point considerably farther north. The data for determining its place in this basin are relatively poor, yet as nearly as could be determined, it passes about five miles north of Arcadia on the east side and two or three miles north of Algoma on the west. The line, therefore, runs more nearly east and west,— about five degrees north of west.

On the supposition that the earth movement recorded in the gages really affected only that part of the area which lay north of the hinge-line, it is evident that Mr. Gilbert did not obtain a true result when he distributed the tilting over the whole distance from Milwaukee to Escanaba. He obtained a rate of 0.43 feet per 100 miles per century, but if the tilting was confined to the 84 miles, which is the distance from the hinge-line to Escanaba, the rate figured by the same method would be about 0.98 feet per 100 miles per century (see Fig. 13). It is believed that this correction of Mr. Gilbert's result gives it full value from the present understanding of the lake history. The remaining pairs of stations used by Mr. Gilbert do not appear to be so easily adjusted to the limits set by the hinge-line. This is true especially of Port Austin and Port Colbourne.

The oldest hinge-line thus far found is one which is recorded in the Whittlesey beach. It passes through about the middle of Lake St. Clair and through Ashtabula, Ohio (see Fig. 11). Neither the Algonquin beach nor the Nipissing extends to the Lake Erie basin, so that the place of their hinge-line in that basin cannot be determined by observation, but only by inference and general relations. If it is parallel with the Whittlesey hinge-line, as it appears to be in the basin of Lake Huron, then it would

lie about four miles north of Dunkirk, New York. This leaves both Port Colbourne and Port Austin about twenty-two or twenty-three miles north of the hinge-line. But the conditions are very different at Port Colbourne, for the outlet of Lake Erie is at its extreme northeast end, and every inch of uplift at Buffalo raises the water-level over the whole of the lake. If the hinge-line is rightly placed, Buffalo is about thirty miles north of it,

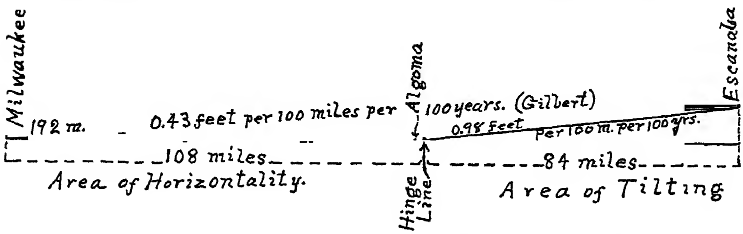

FIG. 13. Diagram showing how Gilbert's estimate of rate of tilting between Milwaukee and Escanaba is modified by taking account of the hinge and the area of horizontality

and almost the whole of the lake is south of it and hence in the area of horizontality. Theoretically, all parts of the shore south of the hinge-line should be flooded the same amount by every inch of uplift at Buffalo. Port Stanley or Erie should show no less flooding than Cleveland, and Toledo and Sandusky no more.[2]

[2] If one supposes the present rate of uplift in the area of tilting to be about 1.5 feet per 100 miles per century, and if one supposes Buffalo to lie about 30 miles north-northeast from the present hinge-line produced from Lake Huron, it is interesting to note the probable effect of continuing uplift on the future status of the lakes. Under these conditions Buffalo is probably being uplifted about 0.5 feet per century. Until the present excessively low stage, Lake Erie was normally about 8 feet lower than Lakes Huron and Michigan, and Lake Michigan lacked only about 8 feet of overflowing at Chicago. With no interference by man at Buffalo or Chicago or anywhere else, the natural course of change would raise Lake Erie to the level of Lake Huron in something like 1,600 years, and in twice that time overflow would begin at Chicago. Then in 1,200 or 1,500 years more the whole discharge would go out past Chicago. The uplift of 0.5 feet per century at Buffalo is extremely slow, but it has gradually flooded all the shores of Lake Erie. Active cutting of the drift banks on the north or Canadian shore is going on nearly all the way from Long Point to the mouth of Detroit River, and has been in progress for a very long time. The heavy cutting at Huron, Ohio, and other points on the south shore is probably intensified by this slow flooding.

In Lake Ontario, Charlotte and Sacketts Harbor are both in the area of tilting far to the north of the hinge-line, and Mr. Gilbert's result is not affected by the present revision.

For about six years the water-level in Lakes Michigan and Huron has been steadily falling and has now reached a stage considerably lower than ever known before, about 577.5 feet above sea-level in December, 1925. The Government made the Livingston channel in Detroit River, and enlarged it later, without putting in any contraction or controlling works above to counteract the strong tendency of the deepened channel to lower the water in the lakes to the north. It looks, therefore, as though the Government had adopted the policy of lowering permanently the water-level in the Michigan-Huron basin, in spite of the great injury that this change is doing to all the people living on its shores. To make the lowering still more effective, building contractors of Detroit have been allowed to take immense quantities of gravel from the great spit at Point Edward opposite Port Huron, although the resistance of this spit was known to account for a foot or more in the height of the water-level in the lakes above. There has been talk of building a dam at Buffalo to raise and control the water-level in Lake Erie. There is great need of some kind of control, but the level of Lake Erie cannot be raised more than a foot or so without doing even greater injury to property interests on all its shores than is being done on the shores of Lakes Michigan and Huron.

This situation has aroused the keen interest of a number of engineers, and among other things, is causing them to see the great importance of the tilting of the land in the Great Lakes region when planning permanent works for improvement or control which look forward over periods of 50 or 100 or several hundred years. In November last, Mr. John R. Freeman, consulting engineer, of Providence, Rhode Island, called my attention to a paper entitled "Tilt of the Earth in the Great Lakes Region," [3] by Mr. Sherman Moore, assistant engineer, U. S. Lake Survey, Detroit. Mr. Moore's paper is of great interest and importance, for he takes up the study of the gage records

[3] *Military Engineer*, May, 1922, pp. 153–155, 181, 183.

where Mr. Gilbert left off thirty years ago. It is very gratifying to see how closely Mr. Moore's results accord with Mr. Gilbert's. In his studies Mr. Moore had all the data that were available to his predecessor and a great deal more besides. Mr. Gilbert was limited to a twenty-year period ending with 1895. Mr. Moore, having brought his studies up to 1925, has thirty years of new and mostly better material in addition to all that Mr. Gilbert had. The fact that Mr. Moore's results are so nearly in accord with Mr. Gilbert's has a powerful cumulative effect toward the truth, so that it is no longer possible for anyone to deny that uplifting and tilting of the lands in the northern part of the Great Lakes region is still going on; indeed, it seems certain that it is affecting a much wider region toward the north, southeast and northwest.

The mean rate of uplift found by Mr. Gilbert from his four pairs of stations was 0.41 feet per 100 miles per century. Mr. Moore's mean found in the same way from nineteen pairs is 0.43 feet per 100 miles per century. In weighing the value of this close accordance it is necessary, however, to take cognizance of the fact that in one very important and rather unfortunate respect Mr. Moore followed the exact method employed by Mr. Gilbert. As pointed out above, Mr. Gilbert wrote his paper before the "hinge-line" and "the area of horizontality" had been fully established. But these modifying conditions have been quite fully described and discussed since that time (*Monograph 53*). Yet Mr. Moore follows Mr. Gilbert and ignores the influence of these modifying circumstances. Both of the engineers mentioned, while readily admitting that hinge-lines and areas of horizontality may have had much importance before the time of gage readings (i.e., before 1875), are inclined to maintain quite strongly that within the gage-measured period (since about 1875, when gage records in sufficient numbers became available) hinge-lines and areas of horizontality do not enter in, and if there is any such thing as a hinge-line or its equivalent in a broad belt of transition from a tilted attitude to horizontality, it must lie some distance south of the Great Lakes region. Let us examine briefly into the bearing of the geological records

of land-tilting upon that of the gage-measured period, into which it merges by imperceptible degrees.

RELATION OF EARLIER TO PRESENT TILTING

Figure 11 shows the region of Lakes Michigan-Huron and Erie, with the area of the ancient beaches south and west of Lake Erie. Crossing the middle of Lake St. Clair, and extending about S. 68° E. through Ashtabula, Ohio, is the Whittlesey hinge-line, the oldest thus far found. At relatively short intervals northward there is a hinge-line for each of the principal beaches, the Warren, Elkton and Algonquin-Nipissing. The last two, with all of the post-Nipissing beaches, converge at one line, the latest line known, and which, as defined above, passes through Grand Bend, Ontario, and crosses the southern part of Lake Huron and Saginaw Bay. The same line less clearly defined crosses the northern part of Lake Michigan. The line shown crossing near Milwaukee is presumably the same as the Whittlesey, but Lake Whittlesey did not extend to that basin. South of the Algonquin-Nipissing hinge-line the Algonquin and all later beaches are now horizontal. South of the Whittlesey hinge-line *all* the ancient beaches are now horizontal. The highest and oldest beach is the Maumee. In the Lake Michigan basin the highest and oldest is the Glenwood beach of glacial lake Chicago, probably a close correlative in time of the Maumee.

The time indicated by the Niagara gorge (approximately say 25,000 years), plus that shown by a few of the recessional moraines, shows that the Maumee and Glenwood beaches have been lying just where they now are for not less than 30,000 or 35,000 years, perhaps longer, and the highly significant fact to be noted is that they are still horizontal, not tilted or warped in a measurable degree. It is reasonable to assume that this attitude of horizontality affects not alone these two beaches, but the whole area between them, and a wide area also to the south and east and west. In New England, certain geologists claim to find a belt of upward bulging of the land outside the glacial boundary, with later depression coincident with resilience farther north. This idea does not seem to apply in the Great Lakes

of land-tilting upon that of the gage-measured period, into which it merges by imperceptible degrees.

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area. It would seem gratuitous to suppose that the Maumee and Glenwood beaches have been raised and lowered or tilted or warped up and back again by a measurable amount to be finally brought back to sensibly perfect horizontality, as though no such movements had taken place.

If the engineers continue to maintain their contention that in the gage-measured period, comprising the last fifty years, there has been no hinge-line nor any area of horizontality within the present lake region, but that the hinge-line or its equivalent, if it existed, lies well to the south beyond the boundaries of the lakes, they will have to prove their case in the face of the facts shown by the Maumee and Glenwood beaches, for it is certain that if there has been any tilting or warping of the land on which these beaches lie within the last 30,000 or 35,000 years, it must have been recorded in these beaches by effects of tilting or warping. It is hardly conceivable that tilting should have suddenly begun to affect the region south of the Algonquin-Nipissing hinge-line in 1875, when it has produced no measurable effect of that kind in so long a previous period, especially when the forces which cause tilting are supposed to be on the wane.

We seem bound to believe, therefore, that discrepancies in the gage readings which seem to indicate land-tilting now going on within the area of horizontality (to the south of the Algonquin-Nipissing hinge-line) are, in all probability, due to defective setting or action or interpretation of the gages. It is absolutely clear that the geological conditions attending land-tilting before the establishment of gage readings come right down to 1875, the beginning of Mr. Gilbert's period of gage readings. That these conditions should have changed so suddenly as to begin an upsetting of the area of horizontality just at that time seems incredible.

It is worthy of note that in the Lake Superior region Mr. Moore finds a tilt rate of 0.94 feet per 100 miles per century, and in Lake Ontario 1.44 feet, and that in both of these areas all the stations used are well to the north of the hinge-line. Is it not somewhat significant that these two rates are so nearly

in accord with the rate found above for the tilting in the post-Nipissing prehistoric period, with its mean rate of 1.48 feet per 100 miles per century, as indicated by the rate of recession in the Upper Great Gorge at Niagara? From his other stations in the basins of Lakes Michigan-Huron and Erie, Mr. Moore gets rates very closely in accord with those of Mr. Gilbert, but in both cases the influence of the hinge-line and the area of horizontality were not considered at all. Mr. Gilbert's rate between Milwaukee and Escanaba, if concentrated in the space north of the hinge-line, gives a rate of 0.98 feet, which is in fairly close accord with Mr. Moore's rates in Lakes Superior and Ontario.

Thus, we seem to find that the rate of land-tilting in the last 2,700 or 3,000 years in the Lake Huron area is in fairly close accord with the rates found from gage readings in the last fifty years *in the area north of the hinge-line,* but that this statement does not apply to the area south of the hinge-line.

Certain features in the Niagara gorge which cannot be dwelt upon here indicate that the falls began making the gorge at the escarpment near Lewiston something like 20,000 or 30,000 years ago, possibly slightly less than the mean of 25,000 years. But some other time values are more accurately determined. For example, the isobase of North Bay, the outlet of the Nipissing Great Lakes, passes about through Mazokama, a few miles east of Nipigon on the north shore of Lake Superior, where Lawson [4] records a strong terrace at 98 feet above the lake or 698 feet above sea-level. At Peninsula Harbor, thirteen miles north of the North Bay isobase (the farthest point north of this line on Lake Superior) the Nipissing beach is a plain of heavy bars 110 to 115 feet (aneroid) above the lake.[5] The stage of

[4] "Sketch of the Coastal Topography of the North Side of Lake Superior, with Special Reference to the Abandoned Strands of Lake Warren," by Andrew C. Lawson, *20th Annual Report, Geological and Natural History Survey of Minnesota*, 1893. Also, "The Nipissing Beach on the North Superior Shore," by F. B. Taylor, *American Geologist*, Vol. XV, May, 1895, pages 304–314. Discusses bearing of Lawson's observations on distribution of Nipissing Beach.

[5] "Notes on the Abandoned Beaches of the North Coast of Lake Superior," by Frank B. Taylor, *American Geologist*, Vol. XX, August, 1897, page 125.

the Great Lakes history known as the Nipissing Great Lakes was a stage of long duration, believed to have lasted 6,000 or 7,000 years. Being on or near the isobase of the outlet at North Bay, the lake stood at or near the level of the Nipissing beach at Mazokama and Peninsula Harbor for this whole period. This explains the extraordinary strength of this beach on the north coast of Lake Superior. The beach in that region began to be abandoned about 2,700 to 3,000 years ago, when the outlet at North Bay was abandoned. South of the isobase of North Bay, the Nipissing beach of this later time (marking the two-outlet transitional phase) is prominent at many places, at Copper Harbor, Marquette, Sault Ste. Marie, Mackinac Island, St. Ignace, Rogers, Alpena, Midland, Owen Sound, Petoskey, Charlevoix, Escanaba, etc. The time factor supplied by Niagara could be followed if space permitted through the earlier stages of the postglacial lake history with equally interesting results.

It is to be earnestly hoped that the engineers will continue their study of this important subject, and that the United States and Canadian governments will give the necessary support. The most urgent need just now is the establishment of two new gage stations, on the most northerly shores, at the mouth of French River on Georgian Bay and at Peninsula Harbor on Lake Superior. The great locks at Sault Ste. Marie are nearly one hundred and fifty miles north of the Algonquin-Nipissing hinge-line, and at the rate of tilting found, the water has fallen away from the locks something more than a foot in the last fifty years, and at the same rate it will fall away more than two feet in the next one hundred years. The governments and the many interests concerned can ill afford to overlook or neglect so important a factor of change.

Fort Wayne, Indiana

GEOLOGY OF ROSCOMMON COUNTY, MICHIGAN

WALTER A. VER WIEBE

THE geology of Roscommon County was studied during the last half of June and during July of 1924 as a part of the investigations conducted by the Land Economic Survey of the state of Michigan.

The geological formations exposed at the surface in Roscommon County all belong to the Pleistocene system and more specifically to the Wisconsin series of glacial deposits. In Roscommon County only three of these glacial types of deposits are present, marginal moraines, ground moraines and outwash plains. See Map 5.

Moraines

MARGINAL MORAINES

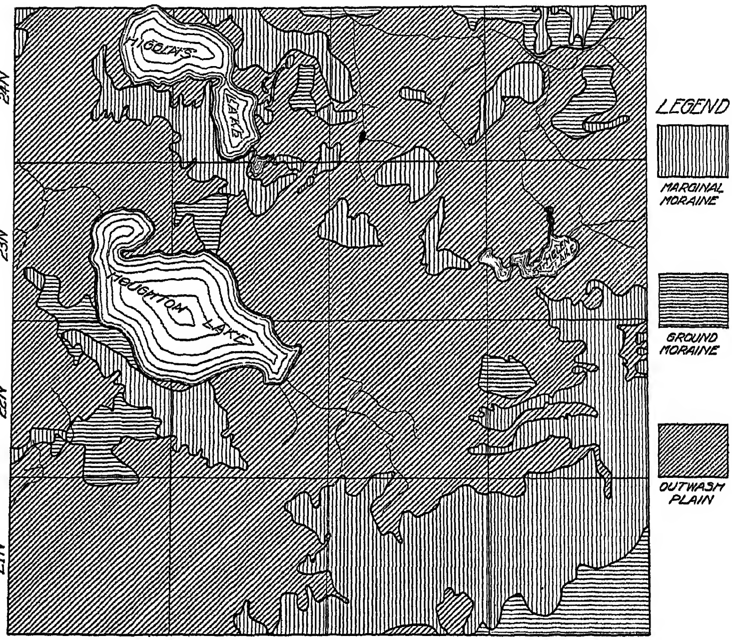
The marginal moraines consist of the following: West Branch moraine, Houghton moraine, South Higgins moraine, North Higgins moraine, and seven small morainic fragments. These will be described in the order of their importance.

West branch moraine. — The West Branch moraine was described in considerable detail by Frank Leverett.[1] It is one of the large moraines formed by the Saginaw lobe of the ice-sheet and only a small part occurs in this county. It was named after the town of West Branch in Ogemaw County, where it is well displayed and can be conveniently studied. It crosses Roscommon County in the southeast portion, extending from Section 33, T. 21 N., R. 3 W., to Section 36, T. 21 N., R. 2 W., along the south line of the county and leaving the county on the eastern side between Sections 25, T. 23 N., R. 1 W. and 12, T. 21 N., R.

[1] Leverett and Taylor, *The Pleistocene of Indiana and Michigan, U. S. G. S., Monograph LIII*, Washington, 1915, pp. 232 ff.

1 W. The northwestern edge of this moraine, which was the side away from the ice, is very much indented and very irregular. In several places tongues nearly five miles long and less than a mile wide reach out toward the west.

On the tongue extending out to Section 24, T. 22 N., R. 2 W.,



Map 5. Geologic map of Roscommon County, Michigan

there are no boulders toward the tip, but quite a few pebbles and much sand. In a cut along the section line between Sections 24 and 19, T. 22 N., R. 2 W., the sand appears to be stratified. On the tongue farther south numerous erratics were observed near the tip in Section 25, T. 22 N., R. 2 W. Both of these tongues are remarkable for their length and narrow width. In other respects, however, they show the characteristics of the main part of the West Branch moraine.

In a general way the outwash side of the moraine may be described as having the 'knob-and-basin' type of topography, whereas the inner side has a 'sag-and-swell' type. This distinction is well brought out on the township road through the middle of Nestor Township, that is, between T. 21 N., R. 1 W., and T. 21 N., R. 2 W.

Houghton moraine. — The Houghton moraine extends across the southern side of Houghton Lake from Section 4, T. 22 N., R. 4 W., to Section 33, T. 22 N., R. 3 W., in a northwest to southeast direction. This moraine was formed by the melting of a transverse lobe of ice lying to the northeast and roughly upon the present site of Houghton Lake. The surface of this moraine is moderately irregular, but it lacks the pronounced accentuation described as occurring on the West Branch moraine.

To the southeast in Section 29, T. 22 N., R. 4 W., lie a number of small morainic knobs. They are about fifty feet high and make a striking contrast with the outwash gravels all about them. A number of gravel pits have been opened in them in which the sand and gravel are distinctly stratified. Because of this fact, these hills may be more properly classed as kames than as simple moraines.

South Higgins moraine. — The South Higgins moraine lies just south of Higgins Lake and extends from Section 10, T. 24 N., R. 4 W., on the northwest to Section 2, T. 23 N., R. 3 W., on the southeast. It resembles the Houghton moraine in being relatively long and narrow. The surface, however, is more sharply irregular than in the latter and its borders are more sharply defined. The northern edge, especially, stands in strong contrast with that moraine because of the well-marked change in angle of slope and its irregular horizontal outline as shown on the map.

North Higgins moraine. — On the north and northeast side of Higgins Lake is another moraine which is very similar to that south of the lake. It also is rather narrow and long. It is characterized by a great abundance of gravel. Pockets of gravel are found chiefly on the northern flank, though some are present on the southern flank. Erratics are fairly numerous and rather evenly distributed. Along M–14 state highway this

moraine is seventy-five feet high above the outwash plain and reaches somewhat greater elevations farther west.

Morainic fragments. — Small fragmentary morainic areas are found between the north and south Higgins moraines on the east side of the lake, a fact which conveys the impression that they were once connected.

All these fragments compare favorably in relief with the larger moraines described. They strongly suggest vigorous stream work practically contemporaneous with their formation such as to produce small hillocks separated from the main mass of ice deposits by deep trenches. Some of these old river channels were filled up by outwash gravels and later abandoned, but others were continuously the site of stream action and are today occupied by streams. The most prominent example of this is the stream known as the 'Cut' which flows east out of Marl Lake, turns sharply south in Section 36, T. 24 N., R. 3 W., and then flows southwest between the main mass of the South Higgins moraine and another isolated morainic fragment. Subsequent additional masses of outwash material brought down from the northeast at a later stage in the ice-retreat almost succeeded in choking up this stream, so that it is now very sluggish and winding.

An interesting fragment in Sections 15 and 22 of T. 24. N., R. 3 W., has the flat surface and gently sloping expression of an old beach. It is twelve feet higher then the present lake level and was no doubt worked upon by the lake waters when they stood at a higher level. A fragment in Sections 14, 15, 22 and 27 of the same township very markedly suggests similar wave-erosion by its elongated, attenuated outline and even crest-line, as well as general and uniform slope toward the present lake. In appearance it resembles a 'spit.' The material is unassorted, however, and too coarse for a normal spit. It might possibly be an ice rampart formed at the higher level of lake water.

Connecting moraines. — There are three fairly large fragments of morainic material in T. 23 N., R. 2 W., which appear to form a connecting link between the Higgins moraines and the West Branch moraine. The reason for the fragmentary nature of this

transverse moraine is twofold. For one thing, the deposition of this transverse (or interlobate) ice-mass was weaker than that of the two main lobes on each side of it because of the shorter time that the ice halted on the retreat. Secondly, it was ideally situated to suffer violent contemporaneous erosion. Strong erosion was accomplished by the great quantities of water which resulted from the melting of the ice as the transverse ice front retreated to subsequent positions farther northeast. These waters were augmented by accretions coming from the melting ice fronts of both main lobes on the sides, since the waters from these also had to pass through the constricted central discharge zone between the Saginaw and Michigan lobes. It is not surprising, therefore, to find the transverse moraines reduced to mere patches and elongated ridges. It is also to be noted that the original relief of these moraines was considerably reduced by subsequent deposition in the drainage channels. If this outwash material could be removed, it would probably be found that some of the moraines are buried under only a slight thickness of sand and gravel.

General character of Roscommon moraines. — In general it may be stated that the moraines of Roscommon County are remarkable for the great amount of sand they contain. In some places the sand is the only constituent and it becomes difficult to decide whether one is dealing with a moraine or a sand dune.

GROUND MORAINES

Loxley ground moraine. — The largest area of ground moraine in Roscommon County is located near the settlement called Loxley in T. 22 N., R. 4 W. The structure of this deposit is shown in a ditch along the east side of the section line between Sections 27 and 28 in front of the house of H. J. Sundberg. This six-foot section reveals the following sequence:

10 in. clay
7 in. fine sand
12 in. clay
4 ft. sand
3 ft. clay

Houghton ground moraine. — On the southwest side of Houghton Lake is another which covers approximately five square miles and connects the Michelson moraine with the Houghton moraine, besides enveloping the northwestern end of the latter. This is perhaps the most typical ground moraine area in the county. It is gently rolling and is composed of clayey material with numerous erratic boulders scattered about evenly, though sparingly, over the whole area.

Markey ground moraine. — North of Houghton Lake in the southwestern part of T. 23 N., R. 3 W. (Markey Township), is a small area which resembles a till plain in many respects. It is very flat, and gives the impression of having been formed on the bottom of a standing body of water. Pebbles are almost wholly absent and erratics entirely wanting. These details lend strength to the supposition that it is a lake deposit. In the absence of complete evidence, however, it was considered a till plain.

Nester ground moraine. — The Nester ground moraine is located in the southeastern part of Nester Township (T. 21 N., R. 1 W.) in the extreme southeastern part of the state. It is the largest till plain area in the county and forms part of a much larger one in adjacent Gladwin and Ogemaw counties. It has considerable relief in places and in this respect is fully equal to some of the morainic patches in the county. In distinction to these, however, it everywhere presents smooth surfaces and gently rounded slopes. Furthermore, the material is more clearly allied to that of a ground moraine than that of a marginal moraine.

OUTWASH PLAINS

Outwash material covers over three fourths of the area which is not under water at the present time. The most typical outwash apron in the county occurs northwest and in front of the West Branch moraine. It shows a low concave slope from the moraine outward. The material shows a definite assortment according to distance from the source. Near the moraine the material is very coarse, consisting almost entirely of cobbles and

large pebbles. At a greater distance from the moraine coarse gravel and pebbles predominate, and at a still greater interval only sand and small pebbles are seen. The third phase usually sets in within a mile of the moraine and from there outward one can expect only sand and pebbles.

Two outwash levels. — In several parts of the county there appear two distinct levels of accumulation. One such area is in Sections 1, 2 and 3 of T. 21 N., R. 3 W. Here the upper terrace lies about fifteen feet above the lower outwash plain. Another place where the two levels appear is in Sections 23 and 26 of T. 22 N., R. 2 W. Whether these two levels represent a lowering of the base level of the streams carrying the outwash or whether the ice formed a temporary dam for the upper terrace will make an interesting problem for future investigations.

An interesting feature of the outwash deposits is the long narrow tongues of such material which appear to extend far back into the moraines. These are especially evident in the lower southwestern part of Richfield Township (22 N., R. 1 W.). Such tongues of outwash are perhaps more properly to be called 'valley trains.' They show a well-defined gradation of material from head to mouth. Near the head cobbles are quite the rule. Another feature is the gradual curve of the slope of the upper surface.

The Lakes of Roscommon County

Houghton Lake. — The largest lake in the county and the largest in the state is Houghton Lake. It covers an area of over thirty square miles, being nearly ten miles long and over four miles wide at its widest point. An outstanding characteristic is the fact that it is very shallow, being scarcely more than fifteen feet deep in its deepest portions and shallower over most of its extent. There are much mud and vegetation over its basin, which accounts for the excellent fishing that annually attracts tourists from all over the state. As regards the cause of the original basin of this lake, it is probable that a number of factors have been operative. Among these the most important is probably the favorable position between two transverse moraines which served to deflect the drainage from the melting ice lying to the

northeast. Most probably it is an example of a 'pit lake,' such as have been abundantly described from other areas.

Higgins Lake. — Higgins Lake has an area of fifteen and one-half square miles. It differs greatly from Houghton Lake in many respects. For one thing it is much deeper. According to most reliable information it has a depth exceeding one hundred feet in many places. Furthermore, the bottom is sandy and gravelly instead of muddy as is Houghton Lake. At the southern end waves have cut into the moraine producing a 'cut-and-built' terrace of considerable width. The line marking the 'drop-off' is very distinct because of the clearness of the water and is marked by a change in color from emerald or grey to a deep azure-blue. Evidences of a former higher level of the water are present at a number of places. For example, in Section 15, T. 24 N., R. 3 E., is a beautiful wave-cut cliff. Farther east is another long ridge extending from Section 22 into 14, T. 24 N., R. 3 W., which appears to have been cut by waves. Evidences of a terrace made at the higher level are to be found in Section 32, T. 24 N., R. 3 W., and to some extent in the section north of this one. For further details regarding the shores of this lake the reader is referred to the excellent treatise on lakes by Irving D. Scott entitled *Inland Lakes of Michigan,* published by the Michigan Geological Survey.

Origin of Higgins Lake. — As regards the origin of Higgins Lake, it may be stated that it appears to be a 'pit' lake. It is possible, however, to assume here also that it owes its existence partly to its protected position between two prominent moraines that offered transverse obstacles to drainage from the retreating ice-sheet.

Clear Lake. — Clear Lake lies at a point scarcely more than a mile south of Twin Lake. It is a horseshoe-shaped body of water occupying a deep irregular depression in the West Branch moraine. As the name implies it is a very clear body of water because it is deep and free from sediment, being fed entirely by seepage waters. The basin of this lake was originally a hole in the West Branch moraine due to irregular deposition of material. It therefore belongs to the class of lakes called 'morainic.'

University of Michigan

SURFACE GEOLOGY OF MENOMINEE COUNTY, MICHIGAN

WALTER A. VER WIEBE

THE rock formations of Menominee County reveal a very interesting geological history for that part of the state. In fact it would be a difficult problem to find an area of the same size anywhere in Michigan which shows a similar variety of geological phenomena. Not only that, but in addition, some of these phenomena are so well displayed and in such profusion that the county may well be considered a typical region for their careful study. These statements apply particularly to the eskers and drumlins.

ICE DEPOSITS

Marginal moraines. — In Menominee County there are two large marginal moraine areas. One of these extends from T. 34 N., R. 29 and 28 W., in a northerly direction to T. 38 N., R. 28 W. This area is marked by the usual rugged, abrupt topography of marginal moraines. The relief amounts to 150 feet in places not more than one-half mile apart. One such spot lies about two miles west of Blom on the north line of Section 33, T. 38 N., R. 28 W. Another is on the north line of Section 25, T. 35 N., R. 29 W.

Eastern marginal moraine. — The eastern marginal moraine extends from the north line of T. 34 N. in a southwesterly direction nearly to the Menominee River just west of the city of Menominee. It is narrow and not any too well defined. There are spots, however, where all the characteristics of a marginal moraine are well displayed and there is no doubt that the margin of an ice lobe halted here for a time on the last Wisconsin retreat.

In Menominee Township the moraine becomes very much attenuated, partly on account of its original narrowness, and partly because the waves of Lake Algonquin have cut cliffs back into it and destroyed portions of it. The highest level of this lake is indicated by a line of wave-cut cliffs and narrow, cut terraces.

Ground moraine. — The ground moraine in Menominee County occupies a strip running through the central part of the county from north to south. It takes in a larger portion of the county than any other type of glacial deposit. In the three northern tiers of townships it extends across the whole width of the county.

It is fairly typical in its surface expression, being gently undulating, in general, except where it is interrupted by drumlins or eskers. It is made up of red boulder clay with occasional erratics. This boulder clay is not always a stiff, sticky clay, but commonly contains a sufficient amount of sand and silt to produce a loamy soil.

DRUMLINS

Distribution. — Among the features that modify the level character of the till plain the drumlins are most prominent. They are present in nearly every township and are so abundant that hardly any square mile is without at least a portion of a drumlin. Over six hundred drumlins were counted in twenty-five townships.

Forms. — Most of the drumlins are elongated hills with very smooth slopes. They are elongated in the direction of major ice movement, which is fairly constant over most of the area, as shown by glacial striae at many places. This direction is S. 40° W., but a slight departure is noted in the western part of the county. See Plate XII, Figure 1.

Most of the drumlins are about three quarters of a mile long. A few are over one and one-half miles long. Most of them show the characteristic tapering off of the profile in the direction away from the ice and the blunt end on the stoss side.

Some of the modifications of drumlin form are rather in-

teresting. For example, double or triple drumlins occur in which two or three parallel ridges are superimposed upon one broad drumloidal arch.

Structure. — Ordinarily the material of the drumlin is unassorted and unstratified. Occasionally, however, a cross-section will show some sections set off from the rest by rude bedding planes, parallel to the surface contour of the drumlin. A good example to show this concentric bedding is one which crosses the center line of Section 23, T. 37 N., R. 26 W., in the east half of the section. In this particular drumlin there are sand zones along the bedding planes. A prominent one is located about four feet below the surface of the drumlin and parallels the contour or profile for a distance of twenty feet. There is a similar one about two feet lower.

Formation. — Many suggestions have been made by geologists to explain the form and other features of the drumlin. None of these fits all cases and it is entirely probable that they may originate in various ways. Indeed, the drumlins of Menominee County furnish evidence in support of at least two explanations.

Chamberlin has suggested that their formation may be in some way related to longitudinal crevassing. Alden [1] found that "the ice of the drumlin-forming segments of the Green Bay Glacier was moving and spreading under conditions which developed stresses along transverse lines; and these stresses, though perhaps not causing the actual opening of longitudinal crevasses, facilitated the spreading of the basal ice about obstructing piles of drift and their formation into drumlins rather than their obliteration by erosion. This condition may also have induced localized deposition in piles or ridges which later were shaped and perhaps added to by the plastering on of drift."

Fairchild [2] believes that "drumlins are shaped by the sliding movement of the lowest ice, that in contact with the land surface. As the ice-sheet thinned by ablation there came a time

[1] Alden, Wm. C., *The Quaternary Geology of Southeastern Wisconsin. U. S. G. S., Prof. Paper*, 106, 1918, p. 255.

[2] Fairchild, H. L., *Drumlins of Central-Western New York, New York State Museum Bull.*, 408, 1907, pp. 429 and 430.

when the drift-loaded ice in contact with the ground was subjected to less vertical pressure and to relatively greater horizontal pressure by the deep ice in the rear, and was pushed forward bodily."

The last explanation seems to agree most closely with the conditions observed in Menominee County, for there is much evidence that the ice mass had thinned considerably at the time the drumlins were formed. The writer's studies on the piedmont glaciers of Alaska lead him to believe that the ice never gets very thin even at the margin. It is conceivable, however, that a large mass might become detached and stranded in the retreat of the main glacier. This relatively stagnant glacier could then be thrust forward bodily by a renewed advance of the main glacier from the rear. It is not difficult to see that such a movement would tend to smooth out small accumulations of boulder till under the stagnant mass and shape them into elongated hills. It also explains how additional layers might come to be plastered on, for melting, with the formation of a layer of till followed by a forward thrust of the ice with its smoothing effect, and renewed melting with the formation of another layer of till and this followed by still another forward thrust, would produce just such a rude stratification or bedding as has been described.

Double and triple drumlins and especially flutings on the till plain, which are common in parts of Menominee County, strongly suggest the erosional effects of ice as the process by which they are produced. If thick masses of ice can produce *roches moutonnées*, there is no reason why lesser ice masses cannot gouge out softer boulder clay and produce elongated grooves such as constitute the troughs between drumlins.

Some unusual drumlins. — On the main road running north from Spalding to Faunus on the south line of Section 33, T. 39 N., R. 26 W., there is a peculiar drumlin. It has the topographic form of a drumlin, being smooth on the surface, oval and elongated in the usual direction. A cross-section revealed by a road-cut and increased by a gravel pit shows a remarkable duality of structure. On the northwest side it consists of alternating layers of gravel, sand and clay. On the southeast side it consists

of unstratified boulder clay with erratics. The north half thus has all the characteristics of an esker, while the south half has the characteristics of a typical drumlin.

The explanation that suggests itself is that an esker stream has cut away a portion of a preëxisting drumlin and deposited, in place of the clay, some sand and gravel. Subsequently the whole deposit was overridden by the ice and smoothed off into the drumlin form.

Dissected drumlins. — Two cases of notable interest came under the observation of the writer in the form of drumlins dissected by an esker stream. One of these is a drumlin which crosses the section line between Sections 10 and 11 of T. 38 N., R. 26 W. An esker which winds along from the northeast for several miles intersects the drumlin in Section 11, T. 38 N., R. 26 W., a short distance north of M–15 and ends somewhat abruptly. At this point there is a trench across the drumlin which cuts through it nearly to the level of the till plain. On the other side of the drumlin in Section 10, T. 38 N., R. 26 W., the esker ridge begins anew and winds south across M–15 and on into Sections 14 and 15 for a distance of nearly a mile.

It appears as though there had been contemporaneous erosion of the drumlin at the time the esker was being formed. Also it is probable that the esker stream began as an eroding stream at the level of the top of the drumlin and did not begin to deposit material until erosion had cut down to the level of the till plain.

An interesting example of the same phenomenon may be seen in the SE. quarter of Section 12, T. 36 N., R. 26 W. Here a drumlin has been cut through nearly to the till plain level. The cut is about 15 feet deep and 25 to 40 feet wide. On the northwest side a somewhat poorly defined esker ridge may be discerned trending NNW. On the southeast side there is quite an amount of stratified sand and gravel, as though a stream had built an alluvial fan out from the point where the esker stream finished cutting through the drumlin, carrying the clay away but leaving the coarser material behind.

THE ESKERS

Perhaps the most interesting feature of the surface geology of Menominee County is the wide distribution of eskers and the unique nature of some of them.

Distribution. — The eskers occur on the till plain, one or more being present in twenty-seven of the twenty-nine townships of the county. The greatest number in any one township is twenty-one (T. 33 N., R. 27 W.) and the next is twenty (T. 36 N., R. 27 W.). They are distributed fairly evenly otherwise.

Forms. — There seem to be two types of eskers in Menominee County which can be distinguished by the forms. One of these is the usual and typical hogback form in which there is a sharp ridge that is nearly as high as it is wide at the base. The other form is flatter and more nearly the shape of a drumlin. Both are characterized by an interrupted profile, and the esker may stop abruptly and then begin again along the same trend farther on. The horizontal profile or ground plan also is quite irregular. Some of them change their direction very suddenly or sharply, turning off nearly at a right angle in extreme cases. Frequently they bifurcate or branch in several directions. See Plate XII, Figure 2.

Trend. — The eskers all show very nearly the same general trend, which conforms in a remarkably close manner to that of the drumlins. In a general way, all the long eskers run from northeast to southwest, and the average would not be far from S. 30° W. Most of the shorter ones also take this direction, but in their case the exceptions are more numerous. Many of these run nearly south and some of them even southeast.

Formation. — It is generally believed that eskers have been built by streams which flowed under the ice, within the ice, or upon the ice. In Menominee County eskers formed by each of the three kinds of streams appear to be present. The low flat drumloidal ridge produced by a stream flowing under the ice is illustrated at a number of places. On the south line of Section 10, T. 33 N., R. 27 W., such an esker crosses the section line road. It is about 20 feet high and 160 feet wide. The peb-

bles in it are well stratified and assorted and most of them average about two inches in diameter. Such eskers are ten to twenty times as wide as they are high and consist predominantly of small gravel and sand.

The opposite type, which, it is presumed, was fashioned by a stream on the ice, is illustrated by an esker three quarters of a mile east of Bagley. In this, the central portion, which consists of very coarse cobbles and boulders, was presumably made by a swiftly flowing stream capable of carrying off all the finer materials. This settled down to the ground with the gradual melting of the ice. The lateral sections, however, consisting of much finer materials were probably the top set beds of the stream which slumped into that position when the ice melted.

The characteristics of this type of esker are, therefore, coarseness of material and greater disturbance of stratification. The relation of width to height in this type is approximately three to one.

A stream flowing within the ice would leave a record of deposition in all essential respects similar to the surface stream. It is logical to assume that the water flowing through such a tunnel would have great force and therefore clean out all finer particles, as silt and sand and even large pebbles. This results in an accumulation of very coarse cobbles and boulders. Most of the eskers of Menominee County are of this last type.

Boulder eskers. — This type may include the peculiar boulder eskers of which a few are found in Menominee County. A boulder esker is one in which occur large erratics or slabs of sedimentary rocks, which in themselves are too large to be moved by a stream. In other respects they have all the characteristics of eskers, such as the serpentine ridge, the assortment, and the like.

The most interesting boulder esker seen is one which crosses M–90 in the NW. quarter of Section 28, T. 39 N., R. 24 W. (one and one-half miles southeast of Shaffer). It is about three quarters of a mile long but twice interrupted, and consists mostly of large, flat slabs of Trenton limestone. Some of these measure over three feet in largest diameter and are arranged with their flat sides parallel to the stratification planes.

Relation of eskers to drumlins. — One of the interesting phenomena that may be seen in Menominee County is an esker crossing a drumlin. In view of the great number of each of these types of glacial deposits, it seems odd that only a few cases of such a superposition appear. Of the two hundred or more eskers in the county only four were observed to rise as high as the crest of a drumlin.

In the SW. corner of Section 17, T. 38 N., R. 25 W., lies one of the most perfectly symmetrical drumlins in Menominee County. It is located on the Sugarbush farm which is well known in that part of Michigan. This drumlin reaches over into Section 19, T. 38 N., R. 25 W. Near its southern end an esker (which starts in Section 16, T. 38 N., R. 25 W.) crosses this drumlin. The esker is rather flat and low on the drumlin, but takes on the steep-sided ridge form west of the drumlin.

KAMES

For the most part the kames are found in a broad zone which trends from northeast to southwest beginning near Perronville in Section 2, T. 39 N., R. 25 W., and extends to Section 29, T. 33 N., R. 27 W. This zone is from six miles wide (near the two ends) to about ten miles wide in the latitude of Daggett. Most of the kames are small in area and not very high.

Formation. — Some kames are made by subglacial streams at the point where they issue because of loss of pressure and velocity. Other kames are made by ice surface streams depositing gravel and washing out boulders into a funnel-shaped basin in the ice. This funnel-shaped deposit later becomes inverted by the melting of its supporting walls. Some kames are formed at points where an esker stream tunnel is enlarged into a cavern.

It is probable that all these types of kames are represented in Menominee County, though it is not an easy matter to pick them out. The first type, which may be called an 'ice-front' kame, may be expected anywhere, i.e. in front of a marginal moraine and anywhere behind it on the till plain. The second type, which we may call a 'kettle' kame or 'moulin' kame, should be most common on a marginal moraine, for where the

ice front stands during a prolonged period of time and melting or ablation is pronounced, there the conditions for surface streams to collect material into holes or moulins would seem most favorable. It is likely that the kames on the eastern marginal moraine of Menominee County in Sections 28 and 32 of T. 34 N., R. 26 W., and Section 1, T. 33 N., R. 26 W., are of this type.

The third type, or 'ice-cavern' kame, might logically be expected to show a rather close relation to eskers. There are several kames in Menominee County which appear at nodes or branching points of eskers. The best example of this kind is near the center of Section 11, T. 38 N., R. 26 W. An esker which begins in Section 1, T. 38 N., R. 26 W., and trends southwest, has several branches, and turns in its course where a hill of irregular outline rises to about twice the height of the esker. The hill covers an area of perhaps an acre and has the hummocky appearance of a kame.

Another interesting kame is to be seen on the south line of Section 29, T. 38 N., R. 26 W. A cut 20 by 140 feet made for road-building purposes reveals a central mass which has the character of a kame and an envelope of boulder till. The central core consists of well-stratified and assorted sand and gravel lenses, but the periphery is made up of only clay and boulders. It appears as though a kame had been formed in the normal way and had later been overridden by the ice and fashioned into a short drumlin.

OUTWASH

The outwash features of Menominee County are of three kinds, viz., kame terraces, outwash and subglacial wash. All of it is more or less perfectly assorted by water action, but it differs in respect to position or mode of formation, so that the threefold division is necessary. The kame terrace will be described first.

Kame terrace. — The name kame terrace was first suggested by Salisbury.[3] He describes it as a deposit made by a stream

[3] Salisbury, R. D., *Ann. Rep., N. J. Geol. Sur.*, 1891, p. 156, and *Glacial Geology of N. J.*, 1902, pp. 121–124.

flowing between an ice mass on one side and a rock mass on the other, and which, on the melting of the ice mass, leaves a terrace of somewhat irregular slope.

Such deposits are fairly numerous in Menominee County. One of the most typical may be seen along the quarter line in Section 25, T. 38 N., R. 26 W., near the west side of the section. A drumlin crosses the road at the extreme west side of the section and on its side an esker is perched. Beyond this to the east is a nearly flat terrace about 75 feet wide. It is composed of small pebbles and sand and at the edge slopes off somewhat irregularly toward the lower land to the east.

One of the best examples in the whole county was observed south of a drumlin one quarter of a mile east of Faithorn in Section 15, T. 38 N., R. 28 W. This kame terrace is 600 feet wide between the drumlin and the railroad.

Outwash. — In Menominee County there are two types of outwash plains which are distinguished by their position with reference to other deposits and also by their size. One type is found in front of the marginal moraine. The other type appears in small patches on the till plain behind the moraine.

The frontal outwash apron associated with the western marginal moraine in Menominee County occupies disconnected patches along the Menominee River. It may be studied in its most typical development in the area north of Shaky Lake. Here it consists of sand and small pebbles assorted and stratified. It is quite thick and shows several levels. In other words, after its original formation, sections of it were removed by streams, so that now terraces are to be seen instead of a simple plain.

The other type of outwash which occurs on the till plain consists of the same material, i.e. sand and gravel. In this case, however, the material is rather fine-grained, the pebbles are quite small as a rule and sand is more common as an admixture. The areas where such outwash is to be seen are quite small in extent and rarely cover more than a square mile. One of the largest areas and also one of the most typical may be seen along M–15 in Sections 4, 5, 9, 10 of T. 38 N., R. 25 W. Small patches occur here and there in a six-mile zone (approximately) extend-

ing toward the southwest through Carney, Bagley, Daggett to Koss.

Subglacial wash. — In addition to normal outwash material and kame terraces, there is another type of deposit which has certain features that set it off from these and make it appear that other conditions are responsible for their deposition than were operative in the case of normal outwash.

This type of deposit is characterized by stream-laid material somewhat irregularly stratified and assorted, but it contains a good deal of coarse material and it lacks the surface regularity of outwash. Instead it is marked by rather broad domes of slightly hummocky aspect or low, flat knolls. Typical areas show no high knolls such as might be called kames nor any ridges that might be interpreted as esker fragments.

In studying these deposits at numerous scattered places in Menominee County one gets the impression that they were formed essentially like outwash plains by waters that result from the melting of the ice, but that these waters flowed *under* the ice instead of in front of it. Hence the name 'subglacial wash' is suggested for such a deposit. It is not difficult to visualize a relatively stagnant mass of ice of large size (such as the front portion of the Malaspina Glacier) left behind in the general retreat of the main glacier. By ablation this mass would in time resemble a limestone region with sink holes, underground channels and caverns. The sink holes of such a honey-combed ice mass are marked by a kame when the ice finally disappears completely. Similarly the underground passages occupied by a stream during the incumbency of the ice are marked by an esker after the ice has melted away. Some of the large caverns and especially those that are low but extensive on the ground level are marked by subglacial wash. For here the streams deposit under pressure and also leave numerous small blocks of ice buried with the rock débris. These two features will produce a hummocky and low, knolly surface when the ice has finally melted. The frequent appearance of large boulders and blocks of limestone is easily explained by assuming that the material was incorporated in the roof of the cavern.

In Menominee County areas where such subglacial wash can be seen are scattered in a broad zone which trends from northeast to southwest and roughly coincides with the zones in which outwash, kame terraces, kames and eskers are most numerous. Perhaps the most instructive area of subglacial wash is the one in the NE. corner of T. 33 N., R. 27 W. It covers a large part of Sections 1, 2, 3, 9, 10, 11, 12, 14, 15, 16.

Record of Lake Algonquin. — In Menominee County the existence of Lake Algonquin is clearly indicated by beach lines and similar evidence in a broad zone bordering the present shore of Lake Huron.

The highest shore-line of Lake Algonquin enters Menominee County in Section 1, T. 37 N., R. 25 W., and winds in and out among the drumlins and other ice-deposits along a line trending southwest. It enters R. 26 W. in T. 36 N. in Section 36, and R. 27 W. in T. 33 N. in Section 25. It reaches the Menominee River in Section 32, T. 32 N., R. 27 W.

In this distance the elevation of the shore-line drops from 655 feet above sea-level at the north end to 620 feet at the south end. It is marked in part by beach ridges, or constructional features, and in part by wave-cut cliffs or destructional features.

Warping of the shore-line. — The highest Algonquin water plane rises from 39 feet (620 A. T.) near Menominee City to 69 feet (650 A. T.) west of Cedar River. It thus shows a rise of 30 feet in about 20 miles or 1½ feet per mile. When compared, the elevations show a drop from east to west also of 20 feet from Fish Creek to Menominee City and of 21 feet from Washington Island to a point 7 miles west of Cedar River. The distance from east to west is 24 miles to the northwest corner of Washington Island and 30 miles to Rock Island. Thus the drop from east to west amounts to about 10 inches per mile in this latitude. The line of equal deformation or isobase would thus run very nearly N. 15° W., which is the angle found by Goldthwait in Door Peninsula.

PLATE XII

PLATE XII

FIG. 1. Drumlin One Mile West of Bark River

FIG. 2. Esker One Mile South of Detgen Farm

LAKE NIPISSING

In Menominee County the Nipissing beach is prominently developed and may be seen at many points. The state highway M–91 enters Menominee County in Section 4, T. 36 N., R. 24 W. For two or three miles southward this highway is built on the Nipissing beach. Numerous cuts along the roadside show stratified sand, gravel, and in places, shingle. Occasionally large slabs of limestone appear intermingled with the gravel and sand. In Section 9 fine stretches of shingle are developed in which 95 per cent of the material is Trenton limestone. Along this stretch of M–91 the elevation of the beach, as determined by hand level, is 27 feet above lake level (608 A. T.).

In Menominee County the shore-line features of Lake Nipissing show a drop in elevation of about 6 feet in 30 miles or 1 foot in 5 miles. This agrees very closely with the figures established by Goldthwait and Hobbs on the basis of careful measurements made in the vicinity of Green Bay.

UNIVERSITY OF MICHIGAN

THE STRATIGRAPHY OF ALPENA COUNTY, MICHIGAN

WALTER A. VER WIEBE

THE observations upon which the data set forth in the following pages are based, were made in the northeastern part of Alpena County. The field-work was done in the month of August, 1924, and June, 1925, for the Land Economic Survey of Michigan. All the consolidated rocks exposed in the county belong to the Devonian system, and the formations in order of their relative age are the Bell shale, the Traverse group (consisting of the Long Lake series, the Alpena limestone and the Thunder Bay series) and the Antrim shale. See Map 6.

Bell shale. — The Bell shale was first described in detail by Rominger on page 49 of Volume III of the publications of the Geological Survey of Michigan (1873–76). At the time of the writer's visit in 1925 the Bell shale was to be seen at only one place in the county. This exposure is in the quarry of the Great Lakes Stone and Lime Co. at Rockport. It may be seen at the north side of the quarry and also at the east end. The first exposure shows a thickness of 12 feet of a soft, blackish or blue, rather massive clay shale. In the greater part of this mass fossils are quite scarce, but in the uppermost eight inches, which is a calcareous mudstone, fossils are very numerous indeed. At the east end of the quarry only a few feet of the shale are exposed under the limestone.

Long Lake or Lower Traverse series. — Grabau, in the annual report for 1901 of the state geologist, divides the Traverse series into three divisions and calls the upper one the Thunder Bay series, the middle one the Alpena limestone, and the lower one the Long Lake series. In this paper Grabau's terminology will be followed, but with considerable modifications as to the rocks

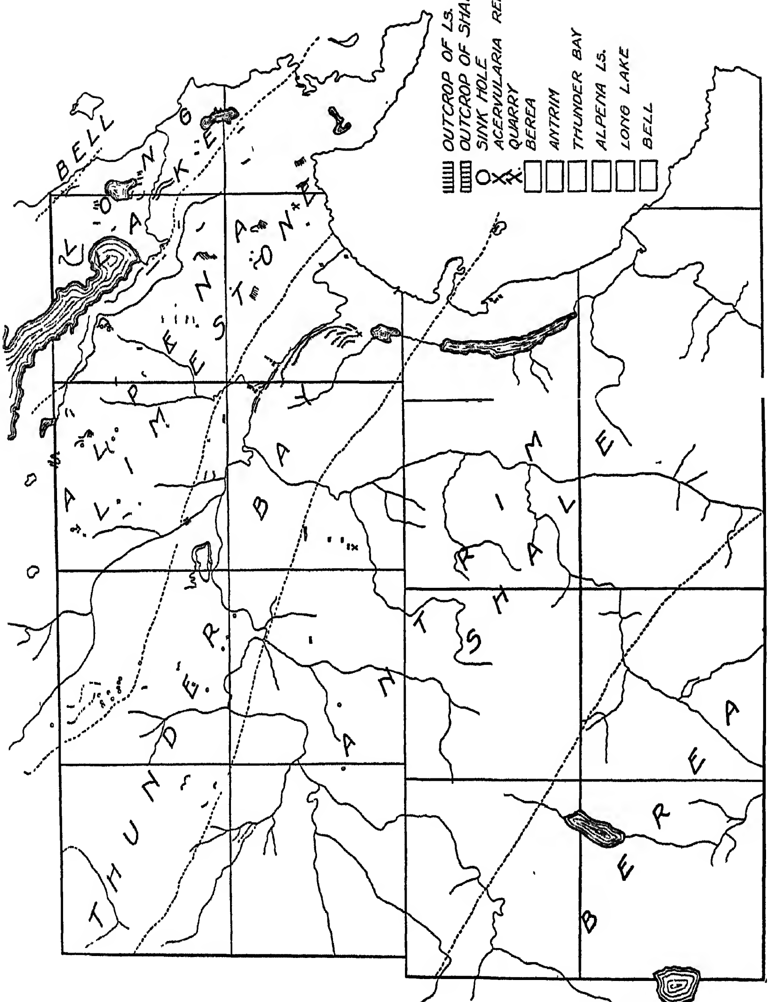
to be included under each name. The Long Lake series, according to Grabau, includes, for example, all the rocks below the 25-foot limestone at the top of the Churchill well (297 feet of section). In this discussion the Long Lake series includes only the basal part of the Traverse (members 7 to 14 in Churchill well), having a thickness of 196 feet. It is felt that such a subdivision agrees more closely with mapable units. Later investigations based on the fossils it contains may make some other grouping more desirable. This series crops out in a zone about three and one-half miles wide, which cuts across the northeast corner of Alpena County from southeast to northwest. In general the outcrops show a thickness of about 80 feet of alternating limestones and shales which form the upper member of the series, below which there are about 70 feet of argillaceous shale (the middle member) and 40 feet of limestone (Rockport limestone) as a basal member.

Upper member of Long Lake series. — The topmost layers of the formation are exposed in Sections 19, T. 32 N., R. 9 E., 24, T. 32 N., R. 8 E., and 30, T. 32 N., R. 9 E. This is Grabau's locality Nos. 29 and 30, described on page 187 of the report for 1901 mentioned above. The writer measured the following section along the section line between 19 and 30 in 1925:

1. Limestone, thin-bedded, in irregular layers, argillaceous and blue	4 ft.	
2. Covered	2 ft.	
3. Limestone, argillaceous, similar to No. 1	3 ft.	
4. Covered	6 ft.	
5. Limestone, argillaceous mudstone		4 in.
6. Shale, clay blue and massive	6 ft.	
Total	21 ft.	4 in.

In the top layer fossils are very numerous. Farther down they also occur, but more sparsely. Very good outcrops of the harder layers in the upper part of the Long Lake series may be seen along the main road to Rockport, especially on the center line of Sections 11 and 12 of T. 32 N., R. 8 E.

Middle member of Long Lake series. — The middle member of the Long Lake series is composed almost entirely of soft shales.



MAP 6. Areal geology and outcrops in Alpena County, Michigan

For that reason outcrops are very rare. The old quarry of the Alpena Portland Cement Co. in the SE. quarter of Section 18, T. 32 N., R. 9 E., was apparently located in this part of the stratigraphic section. It is now abandoned, but was visited by Grabau, who lists fossils from that locality (which he calls locality No. 31). R. A. Smith, the state geologist, has informed the writer that drill holes to test the extent of the Rockport limestone in Section 6, T. 32 N., R. 9 E., encountered as much as 70 feet of shale above the basal limestone of the Long Lake series.

Rockport limestone or basal member. — On page 175 of publication 21 of the *Michigan Geological and Biological Survey* (*Mineral Resources of Mich. for 1915*) Smith first differentiated the Rockport limestone as a stratigraphic unit. He describes it as a limestone consisting of "essentially stromatopora, coral, etc., with a matrix of dark or black crystalline and very bituminous limestone. The stone contains from about 94% to about 98% calcium carbonate."

At the time of the writer's visit in 1925 the quarry opened by the Great Lakes Stone and Lime Co. in this basal part of the Long Lake series was in full operation and exposures permitted thorough study of the characteristics of this member. The following section was measured here:

1. Limestone, buff, lithographic, weathers out in rectangular blocks, and with a characteristic yellow color. Fossils are scarce, but stylolites are common................	10 ft.
2. Limestone, blue, with many large masses of *Acervularia* and *Stromatopora*, as well as innumerable small individual corals. Many black seams and masses of bituminous matter..	12 ft.
3. Shale, bituminous, tough..............................	1 ft.
4. Limestone, forming the lower quarry rock, irregularly bedded, streaky, white, blue, and grey limestone, many bituminous partings. Fossils are numerous, particularly *Acervularia*, *Stromatopora*, and individual corals like *Zaphrentis*, *Cyathophyllum*, etc......	17 ft.
5. Mudstone, calcareous shale filled with fossils.............	8 in.
6. Bell shale, soft, blackish blue, argillaceous................	12 ft.

It will be seen from this section that the Rockport consists of about 40 feet of limestone, most of which is very bituminous.

Another feature is the strikingly different lithology of the upper ten feet, which is buff-colored and very fine-grained and breaks with a blocky cleavage. This part of the Long Lake series corresponds to member No. 14 of the Churchill well record.

The Alpena limestone. — The Alpena limestone was set off from the Traverse as a separate division by Grabau.[1] He assigns a thickness of 25 to 35 feet to it and calls it the "Traverse middle limestone." The thickness is based on the Churchill well, a record of which is given on page 169 of the article.

There can be no question of the possibility of separating the middle portion of the Traverse series from the rest as a distinct lithologic unit. It is sharply bounded above by a most pronounced change in the character of the material, which was laid down in the Devonian seas. There is a change from markedly calcareous shale to a crystalline, hard limestone which seems to be traceable over a large area.

When it comes to a determination of the base of this middle limestone, however, there appears to be no good reason why it should be placed at a depth of 25 or 35 feet, for the same type of rock that characterizes the top of the division continues on down at least 80 feet, as is clearly shown in the quarry of the Michigan Alkali Co. near Alpena. A drill-core taken in the northern part of the same section as that in which the quarry is located shows a thickness of 125 feet of essentially the same kind of rock.[2] If we compare the Churchill well with this record, we find a striking correspondence. Numbers 2 to 6 inclusive are listed as limestone with only two thin shale breaks recorded. The first real shale interval of importance is No. 7, which has a thickness of 20 feet. Below this the shales almost equal the limestone in thickness. It would seem, therefore, more logical to draw the line marking the base of the Alpena division at the base of No. 6 in the Churchill well. This would give a thickness of 126 feet for the whole division. Careful correlation of the various layers of

[1] Grabau, Amad. W., *Stratigraphy of the Traverse Group of Michigan. Geol. Survey of Mich., Ann. Rept.*, 1901, pp. 164–210.

[2] Smith, R. A., *Limestones of Michigan. Mich. Geol. and Biol. Survey*, Publ. 21, *Geol. Series 17*, 1915, p. 181.

the Alpena division in the outcrops northwest of Alpena indicates a similar thickness. Therefore, in this report a thickness of 126 feet will be used as the type thickness of the formation.

Outcrops of Alpena limestone. — A section was made along the Long Lake road by Grabau, the nature of which is discussed in the annual report of the state geologist of Michigan for 1901. He believes that the basal part of the formation (using 35 feet as the thickness) crops out at station No. 19 or locality No. 5, which is a point a few rods north of the northwest corner of Section 35, T. 32 N., R. 8 E. As nearly as the writer can determine, the layers which crop out here lie about 75 feet below the top of the formation, indicating clearly that the thickness assumed by Grabau was one which could not be used in the field. A short distance north of this locality the black zone (lower one) in the formation crops out. This lower black zone appears to come about 35 to 40 feet above the base of the formation. By following the outcrops which are almost continuous from here north, we find evidence of successive limestone layers coming up from below to the surface as far as and beyond the forks in the road (Grabau's locality No. 8, station No. 22).

The lowest layer of the Alpena limestone division has an elevation of about 660 feet, being found about 8 feet above Long Lake where it is first met. This layer, or the ones immediately above it, can be traced toward the northwest so as to allow a correlation with the section at Killian's, where it appears at an elevation of 670 feet above sea-level. It reappears again on the section line between Sections 5 and 8 of T. 32 N., R. 8 E., at an elevation of 675 ft. It continues across Section 6, T. 32 N., R. 8 E., as far as the small lake on the township line in the SE. quarter of Section 1, T. 32 N., R. 7 E. Beyond this point it is difficult to follow because of the steep cliffs and the forest cover. However, the black limestone zone, which lies about 40 feet above it, becomes very prominent here and by means of the latter it is possible to fix the position of the base of the Alpena limestone with satisfactory accuracy.

An important key section may be seen on the Prezinski farm in Section 2, T. 32 N., R. 7 E. The rock succession above a

small lake which enters Alpena County from Presque Isle County in this region is as follows:

1.	Limestone, thin, shaly, buff, crinoidal; makes a good terrace south and southeast of the farm buildings.	1′	1′
2.	Covered..............	21′	22′
3.	Limestone, hard, dense, black, crinoidal, *Favosites*, *Stromatopora*, *Orthoceras*, etc. Elevation about 752 A. T....................................	3′	25′
4.	Covered.	9′	34′
5.	Limestone, massive, hard, buff, crinoidal; just below the level of the buildings at edge of farmyard....	3′	37′
6.	Covered...	14′	51′
7.	Limestone, dark, massive, with numerous corals; makes a prominent terrace....	1½′	52½′
8.	Covered......................	5′	57½′
9.	Limestone, dark, shaly, bituminous.................	1′	58½′
10.	Covered....	4′	62½′
11.	Limestone, very hard, black, crinoidal. Elev. 710 ft. A. T.......................................	1½′	64′
12.	Covered...	24′	88′
13.	Limestone, dull grey, argillaceous, with innumerable *Atrypa reticularis*............	1′	89′
14.	Covered to level of small lake. Elev. 680 ft. A. T....	6′	95′

Layer 11 in the foregoing section is a very prominent terrace-making rock and can be traced to the southeast through the woods as far as the Donakowski farm, where it forms the top-most terrace under the buildings and the barnyard. It can be traced farther to the southeast through Sections 7 and 8 of T. 32 N., R. 8 E., and appears to be equivalent to a part of the prominent black zone in the Killian section. By means of this layer, therefore, the sections southwest of Long Lake can be correlated. If the correlation is correct, it develops that the base of the Alpena limestone lies below the level of the little lake in Section 2, T. 32 N., R. 7 E. Accordingly the line between the Alpena and lower Traverse passes through Section 35, T. 33 N., R. 7 E., about a half-mile south of Long Lake.

Thunder Bay or upper Traverse rocks. — The uppermost division of the Traverse group has been named the Thunder Bay series. It has received the least attention on the part of geologists of any of the divisions of the old Hamilton group of Rominger. For that reason the writer spent considerable time and

effort in tracing the various members of this division. He was able to find outcrops which show nearly every individual portion of the division at one place or another. Also by careful comparisons he was able to trace certain members along from one outcrop to another, so that a complete section of the whole division might be built up. This section is as follows:

1. Limestone, blue to pale buff, crinoidal; weathers rusty-yellow or brown, many corals	5′	5′
2. Limestone, argillaceous, with thin beds of calcareous shale, very fossiliferous	7′	12′
3. Covered interval	?	
4. Limestone, dull grey, crystalline; weathers out in flat pieces with a rusty color	1½′	13½′
5. Covered	1′	14½′
6. Limestone, dense, hard, bluish-grey; weathers out nearly white, microcrystalline	2′	16½′
7. Covered	1′	17½′
8. Limestone, dark grey to blackish-brown, semi-crystalline; crinoids, corals	6½′	24′
9. Limestone, similar to No. 8	1′	25′
10. Limestone, hard, brittle, dense, grey	1′ 2″	26′ 2″
11. Limestone, blue; made up almost entirely of silicified corals	1′	27′ 2″
12. Limestone, similar to No. 10	10″	28′
13. Shale, calcareous, with bituminous streaks	1′ 3″	29′ 3″
14. Limestone, blue, thin-bedded, many fossils	2′	31′ 3″
15. Shale, calcareous, blue and black	9″	32′
16. Limestone, very massive; weathers out in peculiar nodular masses when fresh, and in red or yellow, porous, crumbly masses when weathered for a long time	2′	34′
17. Limestone, dark brownish-buff, shaly on top	1′	35′
18. Covered	2′	37′
19. Limestone, yellow to buff	2′	39′
20. Limestone, shaly, crinoidal, rusty outcrop	1′	40′
21. Limestone, hard, buff, microcrystalline	1′	41′
22. Limestone, similar, but top is coarsely crinoidal	2′	43′
23. Shale, calcareous, blue; weathers rapidly with rusty discoloration, very fossiliferous, in SE quarter of Section 20, T. 31 N., R. 8 E.	19′	62′
24. Silo Terrace. Limestone, grey, encrinal, semi-crystalline; weathers buff, yellow and red; fossils	8′	70′
25. Shale, blue, calcareous, very fossiliferous	3′	73′
26. Alternating layers of argillaceous limestone and calcareous shale, less fossiliferous	10′	83′
27. Covered	11′	94′

28.	Shale, blue, calcareous; disintegrates readily into blue clay....	10′	104′
29.	Limestone, blue, argillaceous, shaly,................	2′ 4″	106′ 4″
30.	Shale, blue, clay shale; weathers rapidly, fossils....	3′ 6″	109′10″
31.	Limestone, blue, argillaceous, shaly	10′	119′10″
32.	Same as No. 31..................................	2′ 2″	122′
33.	Covered..	?	122′ ?

Nos. 1 and 2 of the foregoing geologic section are typically exposed at Partridge Point. The black shale was not found directly above the limestone here, but it was found in two wells drilled by the Alpena Business Men's Association in Section 22, T. 30 N., R. 8 E., at such a depth as to indicate that the limestones found on the point are practically the top of the formation. The very top layers are exposed only at one locality. North of the quarter line in Section 17, T. 31 N., R. 7 E., large pieces of crinoidal limestone similar to those at Partridge Point may be seen in an abandoned field. South of the quarter line on the land of Mr. Patterson are very good outcrops of the black (Antrim) shale. This is probably the only place in the county where the exact contact between the upper Traverse and the Antrim shale is to be seen.

The covered interval (No. 3) probably does not exist at all. In fact, it is more than probable that Nos. 1 and 2 in the section find their counterpart in Nos. 4 to 8 inclusive of the section. In that case we have instead of a covered interval, a duplication of 12 feet. If this duplication is allowed for, the whole section would total 110 feet as a minimum and 140 feet as a maximum. Nos. 4 to 24 are the composite section made for the Potter farm (Section 20, T. 31 N., R. 8 E.). The rocks exposed on Orchard Hill are in all probability the equivalent of Nos. 22, 23, and 24. The limestone which crops out on Stony Point is about the same horizon as Nos. 21 and 22 in the composite section.

No. 24 is an excellent key horizon. It makes a prominent terrace on the Potter farm and because of the fact that a high, hollow-tile silo, which can be seen for miles, stands directly on it, the writer has called it the Silo Terrace. It crops out practically uninterruptedly from the Thunder Bay River in the SE. quarter of Section 20, T. 31 N., R. 8 E., in a northwest direction to Sec-

tion 12, T. 31 N., R. 7 E., and therefore makes a convenient datum plane for the rest of the geologic section above and below. Nos. 16 to 20 also make well-defined terraces, but they must be used with caution as any one of the four benches may make the terrace. The peculiar nature of No. 16 will serve to identify the horizon of the terrace.

No. 23 is the zone that offers the happy hunting-grounds for the collector of fossils. It is doubtful whether there is a more prolific source of fossils than this zone as exposed in the SE. quarter of Section 20, T. 31 N., R. 8 E., and the adjacent part of Section 21, T. 31 N., R. 8 E. These are Hindshaw's localities Nos. 7 and 9.

Nos. 25 and 26 are exposed on the north side of Thunder Bay River west of the upper dam in Sections 1 and 12 of T. 31 N., R. 7 E. No. 28 is exposed at several places. The full ten feet show up where the line between Sections 17 and 18, T. 31 N., R. 8 E., crosses Thunder Bay River in the south bank. A portion of this clay shale also shows in the south bank below the lower dam and again in the south bank below the upper dam.

Nos. 29, 30 and 31 may be studied at the Fletcher (lower) dam. They are Nos. 8, 9 and 10 of that section. The equivalents of the same layers probably occur also below the upper dam. There they would correspond to Nos. 3 and 4 of the geologic section for that particular section. No. 32 is exposed along the township road between Sections 1, T. 31 N., R. 7 E., and 6, T. 31 N., R. 8 E. This correlation is not as precise as might be wished, but close enough for all practical purposes.

The final covered interval at the base is entirely conjectural. Inasmuch as there is a slight gap between the lowest outcrops of the lower Traverse and the upper beds of the Alpena limestone, it is likely that 10 to 15 feet of calcareous shale are present in this part of the stratigraphic section. It is not certain, however, that there is any interval and on the other hand it may be as great as 30 feet in thickness.

Antrim shale. — Outcrops of the Antrim shale are not numerous in Alpena County because the shale is so easily destroyed by weathering agents, and also because of the thin sheet of glacial

drift which obscures so large a part of the consolidated rocks of this region. The best place to study the formation is in the quarry of the Huron Portland Cement Co., which is located in Section 30, T. 31 N., R. 7 E., in the northeast quarter of the section.

The concretions found in the shale are of two kinds. The large ones consist chiefly of calcium carbonate with some clay and iron carbonate as impurities. They are very numerous in certain zones. In size they range from eight inches in diameter to over three feet. During past years of quarrying thousands of these 'hardheads,' as the drillers call them, have been uncovered. They now lie in the bottom of the quarry in long rows where they were left because they form an objectionable impurity in the shale. Consequently they offer a unique opportunity for study and it is hoped that someone who is interested in their mode of formation will take advantage of this opportunity before they are covered up. The writer was impressed by the fact that many of them have a bituminous calcite (called anthracolite) as a central core. Even more suggestive is the fact that this calcite shows by its strong elongation of one axis of growth (the 'c' axis?) that this mineral has grown from the center outward. A core of this type will, therefore, show crystal growth radiating in all directions from the center outward. Other concretions that were examined show only a cavity in the center, sometimes of large size. In still others this cavity was filled in geode form with secondary calcite, siderite or magnesite or rarely with quartz. In some concretions the shale shows a tendency to arch up and down, that is, around the concretion as if the latter had grown after the shale was laid down.

The second kind of concretion which is abundant in this shale is a form of iron sulphide, probably pyrite. It also occurs at all levels, though it is frequently found in definite rows at certain levels in the section. Masses of this mineral are not so uniformly round or oblately spherical as masses of the other material. Besides being irregular in shape they are also much smaller. Concretions of the size of a large walnut are most common and many are of the size of a large apple.

Fossils are rare in this shale. The writer found one piece of a kind of Calamite stem and a few fragments of a Devonian fish. The latter was found in the center of a single concretion which had been broken open and the fossil was, therefore, broken into many fragments. It may lend itself, however, to identification and may prove to be a new genus. No systematic search for microscopic fossils was made.

Outcrops of the Antrim shale. — Outcrops of the Antrim shale occur at three other localities in the county. One of these is in Section 17, T. 31 N., R. 7 E., another in Section 15, T. 31 N., R. 6 E., and the third in Section 22, T. 30 N., R. 8 E. The first one of these is probably the most interesting as it marks the precise boundary line between the Antrim and the Traverse formations.

UNIVERSITY OF MICHIGAN

PRINCIPLES OF OTTOMAN FOREIGN POLICY

NICHOLAS S. KALTCHAS

I

THE Treaty of Carlovitch (1699) has been generally accepted as marking the passing of the Turkish menace and the beginning of the decline of the Ottoman Empire. Its claim to this distinction, however, can be as easily disputed as those of most of the so-called landmarks in history. As a check to Ottoman expansion, it was preceded by nearly one hundred years by the Treaty of Sitvatorok,[1] while that of Belgrade, which followed Carlovitch by exactly forty years, marked such a pronounced recrudescence of Ottoman aggressiveness as to justify serious doubts regarding the reality of Ottoman decadence.

These doubts, however, were completely dispelled by the Treaty of Kutchuk Kainardji, signed in 1774, at the close of Russia's first successful war against Turkey. So far as a mere peace treaty can be regarded as the turning point in the history of a state, Kutchuk Kainardji is entitled to this distinction in the history of the Ottoman Empire. For the first time, commercial privileges, which up to that time had been granted by the Porte to friendly nations, were wrung from it as the penalty of defeat by a hostile power. The extortion by Russia of the long overdue right of free navigation in the Black Sea gave birth to the perennial and insoluble problem of the Straits; while the recognition of Russia's interest in the welfare of the Sultan's Christian subjects established the principle of European interference in the internal affairs of the Empire and gave the first strong impetus to the separatism of its subject nationalities.

[1] Hammer, Joseph von, *Geschichte des Osmanischen Reiches* (10 vols., Pest, 1827–1833), IV: 393–396.

Kutchuk Kainardji, in short, contained the Eastern Question in embryo. It sealed the conversion of the Ottoman Empire from a menace to the safety of Europe to an object of European ambition and transferred the question of partition from the field of academic speculation to the lower but more alluring plane of practical politics. By reducing it definitely to the defensive, it deprived the Ottoman Empire of its initiative in international affairs and compelled it to adjust itself more and more to courses set by others; in other words, to play the diplomatic game as it was understood and played by the sovereign states of Europe. Hence, Ottoman foreign policy since 1774 has gradually adopted the fundamental principles of the so-called public law of Europe, adapting them, of course, to Turkish conditions and Turkish character. Ottoman diplomatists have, since 1774, assiduously gone to school to the hitherto despised Westerners and, by a combination of Western principles with Eastern methods, have learnt to beat them at their game.

But during the three centuries preceding Kutchuk Kainardji the Ottoman Empire had shown remarkable originality in its intercourse with other states. Indeed, in the heyday of its power the foreign policy of the Empire and its diplomatic technique were almost as distinctive as its contemporaneous military organization and political institutions. It will be my endeavor in this paper to point out the most striking peculiarities of Ottoman foreign policy during the period of Ottoman expansion; and by so doing to offer a partial explanation of the failure of the Ottoman Turks, in spite of their enormous military strength, to strike at the heart of the feeble and disunited Europe of the sixteenth and seventeenth centuries and thus seriously to imperil western civilization.

II

The Ottoman Empire was founded by war. Its political and administrative system was an amplification, with Persian, Arab and Byzantine accretions, of the primitive military organization of the nomad warriors of Central Asia. Its history for four centuries offers an almost uninterrupted record of fighting,

being, as a keen observer has remarked, "almost exclusively a catalogue of names and battles."[2] But the wars waged by the Ottoman Empire were not "an instrument of policy," "a continuation of political commerce, a carrying out of the same by violent means,"[3] but rather the normal kind of relationship with territorially contiguous states. With its neighbors — Persia in the East, the Mameluks in the South, Muscovy, Poland and the Austrian Hapsburgs in the North, the Spanish Hapsburgs and Venice in the West and on the Mediterranean — the Empire was regularly at war.[4] The countries beyond the Empire's borders constituted the seat of war — *Dar-ul-Harb* — to be invaded and conquered by the Ottoman armies.[5] Peace was merely an interval between two wars; it was purchased by the invaded country through payment of tribute in annual instalments, which were not an indemnity in the western sense, but rather a bribe to induce a cessation of hostilities. A peace treaty meant that for a consideration, which was also a symbol of Ottoman victory, the Ottoman Empire would abstain from attacking the other contracting party over a specified period of years, at the end of which it would resume its freedom of action. This truce, however, did not involve entire cessation of hostilities along the constantly fluctuating border, and it was often officially violated before the expiry of the stipulated term. For so deep-rooted was the conception that the foremost duty of every Ottoman sovereign was to make war, that a peace treaty concluded by one Sultan was not regarded as binding on his successor.[6] The truce between Poland and Turkey was

[2] Odysseus, *Turkey in Europe* (London, 1900), p. 62.

[3] Clausewitz, Karl von, *On War*. Translation by J. J. Graham (2 vols., London, 1911), I: 23.

[4] "The Pope . . . having no confines bordering on the Turks, his riches, power or greatness seldom falls as a subject for their consideration." — Ricaut, Sir Paul, *The History of the Present State of the Ottoman Empire* (London, 1686), Chapter XXI.

[5] Lybyer, A. H., *The Government of the Ottoman Empire in the Time of Suleiman the Magnificent* (Harvard University Press, 1913), p. 29.

[6] "The death of a Sultan may bring war with it; for *omnia cum eodem simul decesserunt* is for the Turks an old and unalterable principle of state." — Jorga, Nicolae, *Geschichte des Osmanischen Reiches* (5 vols., Gotha, 1908–1912), III: 79.

renewed in 1553 expressly until "the death of the king and of the almighty emperor of the Turks." [7] And it was a signal victory for Hapsburg diplomacy when it was able to include in the Treaty of Sitvatorok, the first one that resulted from negotiations and not from Ottoman dictation, the stipulation that the peace was to last for twenty years irrespective of change of sovereign, as well as to substitute a lump sum of 200,000 ducats for the humiliating annual payments of tribute.

This inveterate belligerency of the Ottoman Empire should not be attributed, as it often has been, to religious motives. The Ottoman rulers were not crusaders burning with zeal to propagate Islam by the sword. Quite apart from the contradictory injunctions of the Koran on the subject and their latitudinous interpretation by Mohammedan jurists, it is a notorious fact that the Turks neither hastened to convert the conquered infidels nor hesitated to make war on other orthodox Mohammedan states, like Syria and Egypt, whose Mameluk rulers in turn did not disdain to invoke the aid of Christian princes [8] against their fellow-Mohammedans. Nor did Selim the Grim, the first Ottoman caliph, and his successors rely on the mere spiritual authority of their office to effect the unity of the Moslem world. The authority of the caliph did not extend beyond the reach of the mighty sword of the Ottoman sultan, just as it was the strength of the Hapsburg rulers that lent any substance to the claims of the Holy Roman Emperors. The Moslem world has been no more united politically than the Christian world and the myth of Islamic unity, so skilfully exploited by recent Turkish rulers from Abdul Hamid to Mustapha Kemal as a means of exerting pressure on European governments, derived its potency from the amount of credence which Western Europe was willing to give to it.

But while religious proselytism was not the primary motive behind the wars of the Ottoman rulers, it was doubtless religious zeal more than any other factor that justified these wars in the eyes of the Turkish people and stimulated the ardor of the Ottoman armies. "As a people believing in the almighty Allah,

[7] *Ibid.*, p. 113.

[8] Jorga, N., *op. cit.*, II: 248.

whom they always and everywhere worshipped and served, . . . as warriors who had never been left in the lurch by their God. . . they had the right after long experience to feel that their especial calling was war." [9] Moreover, before embarking upon a war the sultan was careful to establish its religious character by securing its authorization by the Mufti, the supreme interpreter of the Sacred Law. Having decided to wrest the island of Cyprus from Venice, Selim the Drunkard, the successor of Suleiman the Magnificent, asked the Mufti of the day whether there was any reason "according to the pure law" why the peace treaty with the Republic should not be broken. The Mufti's answer invoked the precedent of the Prophet himself who did not hesitate to break the four-year treaty which he had concluded with the infidels and to attack and conquer Mecca. Based on this precedent of unassailable authority, the Mufti's decision laid down the rule that it is imperative for the Prince of Islam to violate a treaty with the Infidels if he can thereby secure some benefit for the totality of believers.[10]

This procedure did not differ materially from the way in which the *raison d'état* in the Christian states of the West has been bolstered up by recourse to the law and, more recently, to the higher morality. Frederick the Great's peremptory injunction to his ministers to devise some legal justification of the seizure of Silesia and Louis XIV's Chambers of Reunion are cases in point. But the *fetvas* ('decisions') handed down by the Mufti contained, owing to the theocratic character of the Ottoman state, both a legal and a religious authorization of the war contemplated by the Sultan. Selim the Grim's war against Persia was undertaken primarily in order to destroy the powerful Persian Empire. But a decidedly religious flavor was given to it by the fact that the Persians were Shiites, i. e. heretics, from the point of view of the Sunnite Turks. The Mufti's decisions, in other words, reconciled the *raison d'état* with the highest religious duty of a Mohammedan. A war thus authorized became a Crusade, a Holy War, *Jihad;* and those who died while engaged in it were *shehids* ('martyrs') and went to heaven

[9] Jorga, N., *op. cit.*, III: 78.

[10] Hammer, *op. cit.*, III: 566.

and all its allurements without first passing through the various stages of Mohammedan purgatory. To sum up, the foreign wars of the Ottoman Empire, while as secular in their aims as those of the contemporary states of Western Europe, invariably received a religious sanction through the *ad hoc* decisions of the highest interpreter of the Sacred Law, a procedure which on the whole proved a source of inspiration and moral strength.

III

It is when we try to discover the specific secular aims that motivated this incessant warfare that the peculiarity of Ottoman foreign policy becomes apparent. In the West war was waged almost as frequently as by the Ottoman Empire, as the most efficacious means of building up a state. "A Prince," wrote Machiavelli, "ought to have no other aims or thought, nor select anything else for his study than war and its rules and discipline; for this is the sole art that belongs to him who rules, and it is of such force that it not only upholds those who are born princes, but often enables men to rise from a private station to that rank." [11] Territorial aggrandizement was the great aim of foreign policy and war its ultimate instrument; for "the wish to acquire is in truth natural and common and men always do so when they can and for this they will be praised not blamed." [12] "He who gains nothing loses," was Catherine II's expert opinion delivered at the end of a long reign in which territorial aggrandizement had figured very prominently.[13] Hence the two conceptions of foreign politics dominant in Europe during the Old Régime and, in a modified form, for all our unwillingness to admit it, up to the present time: the doctrine of natural boundaries and that of the balance of power.

Now an examination of the history of the Ottoman Empire during the period of its greatness will reveal the startling fact that neither of these principles guided the foreign policy of the

[11] Machiavelli, N., *The Prince*, Chapter XIV.

[12] *Ibid.*, Chapter III.

[13] Catherine to Grimm, February, 1794. Quoted by Sorel, A., *L'Europe et la Révolution Française*, I: 19.

most inveterately aggressive state of modern times. If the Ottoman rulers had been fighting in order to acquire natural boundaries in Europe, their career of conquest should have stopped with the acquisition of the Danube, the Transylvanian Alps and the Pruth. But war went on with brief interruptions long after these splendid boundaries had been attained and the Empire's capacity for conquest had been spent; for, because of its peculiar structure, war was as much an inner necessity for the Ottoman Empire as peace is for other states. Territorial expansion was only incidental and often not as important as the tribute which invariably accompanied the conclusion of peace. This attitude accounts in part for the singular lack of perseverance characteristic of many Ottoman campaigns. It was more important that the Ottoman army should take the field every year than that it should be able to show tangible results of its activity. For the Ottoman Empire was a huge, unwieldy military machine which had to be constantly in action. "This so constituted organization had need of two things: it needed for its animation a man filled himself with a vivid spirit and free and mighty impulses, and to give it movement and activity it required continual campaigns and progressive conquests: in a word, war and a warlike chief." [14]

War became still more imperative with the disappearance of the great fighting sultans and the military decline of the Empire. For it gave the Janissaries something to do, held out to them the prospect of booty and rid Constantinople and the other cities of their turbulence and the sultan of the subversive praetorianism in which they indulged when idle. It replenished the slave market with the captives of war and the sultan's treasury with the tribute paid by the enemy as the price of peace. Most important of all, it served to enhance the glory and prestige of the sultan and to put an end to internal disorder and anarchy. That is why, whenever the Empire was in the doldrums, war was resorted to as the surest remedy. The conquest of Crete was undertaken in the middle of the seventeenth century when

[14] Ranke, Leopold, *The Ottoman and Spanish Empires in the Sixteenth and Seventeenth Centuries.* Quoted by A. H. Lybyer, *op. cit.*, p. 111.

the Empire was on the verge of dissolution because "such a conquest and especially the war leading thereto was unavoidable under the existing conditions."[15] The war thus begun against Venice was soon extended to Austria and for over half a century, under the Kioprulus, an army was put in the field every year in order to "take a fortress, a castle or a town whose real importance was of no consequence since the Empire had long since reached its natural boundaries . . . so as to give the Sultan the illusion of a great victory and of a fresh conquest."[16] The disaster of St. Gothard, the repulse before Vienna and the crowning humiliation of Carlovitch were the price which the Empire paid for indulging its weakness for protracted and aimless warfare.

IV

In the handling of the diplomatic problems incidental to these wars the Ottoman Empire was unique among its contemporaries. With the exception of the Phanariot Greeks, who never possessed much power or initiative, Ottoman statesmen did not know the meaning of diplomatic preparation for war. To single out one state as the most dangerous potential enemy, to isolate it internationally by securing the benevolent neutrality or, through a formal alliance, the active coöperation of its neighbors, never to weaken, much less destroy, any weaker power likely to act as a check to its ambition, these are the fundamental rules of western statecraft first observed by Machiavelli in Italy and subsequently practiced on the larger European stage by such masters as Henry IV, Richelieu, Louis XIV, Kaunitz and Frederick the Great.[17] But these canons were ignored by Ottoman diplomacy. The principle of freedom from entangling alliances was practiced by Ottoman statesmen long before it was erected into a dogma on this side of the Atlantic. The assistance given by Suleiman the Magnificent to Francis I was too one-sided to be called an alliance. It was rather a grand gesture,

[15] Jorga, N., *op. cit.*, IV: 35.
[16] Jorga, N., *op. cit.*, IV: 186.
[17] See Machiavelli's discussion of the mistakes committed by Louis XII in Italy. — *The Prince*, Chapter III.

a spontaneous exhibition of somewhat contemptuous magnanimity on the part of the sultan towards a Christian under dog and was promulgated, characteristically enough, not in a bilateral treaty but as an imperial decree (*Hatti-Sherif*).[18] So much did Suleiman relish the rôle of the mighty protector who demanded nothing in return from his protégé because he did not need his help, that he winked at Francis' lukewarm prosecution of the war against Charles V and repeatedly came to his assistance even after he had "fraternized" with the Hapsburg Emperor.[19]

Apart from this *beau geste* of Suleiman, the Ottoman Empire adhered strictly to its policy of "splendid isolation." It fought its wars single-handed and invariably resisted the solicitations of various European powers that were courting its coöperation against their common enemies. Although Spain was its enemy, it remained neutral in the struggle between Philip II and Elizabeth, in spite of the latter's and Henry IV's efforts to effect an alliance by promising it a part of the Kingdom of Naples.[20] In 1627, in the midst of the Thirty Years' War, the Porte renewed for twenty-five years the peace of Sitvatorok with Austria when, by coöperating with Richelieu, it could have given the *coup de grâce* to its most persistent enemy. Though almost constantly at war with this same power during the reign of Louis XIV, it steadfastly refused to join forces with him and persisted in its aloofness even during the War of the Spanish Succession when an alliance with the hard-pressed king of France might have avenged Carlovitch. It went still further in its disregard of the rudiments of statecraft. It attacked Venice just when Austria, having been freed from her western troubles by the Treaty of Utrecht, was able to come to her assistance; and thus gave Prince Eugene of Savoy an opportunity to inflict

[18] "The Grand Signior . . . wants no treaties with Christian Princes contending that they are not his equals. He prefers the term capitulations which he grants and may revoke, restrict and annul without ceremony whenever he deems it necessary." — Chevalier d'Arivreux (Laurent d'), 1635–1702, *Mémoires* (Paris, 1735), 6 vols. Quoted by De la Jonquière, Vicomte A., *Histoire de l'Empire Ottoman* (Paris, Hachette, 1881), p. 236.

[19] Jorga, N., *op. cit.*, III: 88–89.

[20] Jorga, N., *op. cit.*, III: 396.

upon the Ottoman armies the greatest defeats they had yet sustained and to dictate the Treaty of Passarovitch (1718). The same proud isolation was maintained, in spite of the efforts of French diplomacy, during the War of the Austrian Succession; while all the blandishments of Frederick were unable to induce the sultan to help him in the Seven Years' War, in his life and death struggle against both Austria and Russia, the Ottoman Empire's perennial enemies.

With the reign of Peter the Great Russia began to loom as a still more formidable menace. Sweden and Poland were Russia's enemies and it would have been the part of elementary wisdom for the Porte to help the former and, if not to strengthen, at least to do nothing that would tend to weaken the latter. A close alliance with Charles XII, that redoubtable military genius, would have been Peter's undoing. Yet not only did the Porte reject such an alliance but, in spite of Charles' frantic protests, it ratified by the Treaty of Adrianople (1713) the extremely lenient truce of 1711, which had saved the Russian army from annihilation and Peter himself from certain capture.

As for Poland, the Porte treated her as an enemy only less consistently than it did Austria. The acquisition of a province, a town, a fortress, or the payment of several thousands of Polish tribute into the Sultan's treasury was more important in the eyes of Ottoman statesmen than the preservation of the strength and the good will of Russia's enemy. Such was the Porte's blindness to its true interests that by the Treaty of November 16, 1720, it fatuously associated itself with Russia in the latter's efforts to maintain intact the Polish constitution which with its *liberum veto* and the emasculation of the royal power was the greatest source of Poland's weakness.[21] It was only after they had been lectured by the unofficial and official diplomats of France — Bonneval, Tott, Villeneuve, Vergennes and St. Priest — that Ottoman statesmen became convinced that a strong Poland was essential to the existence of their Empire. The immediate consequence of this belated conversion was the War of 1768, an eleventh hour attempt to save Poland, which by a strange

[21] Hammer, *op. cit.*, VII: 256.

irony resulted in the first partition and, for the Ottoman Empire, in the humiliating peace of Kutchuk Kainardji.

V

This disregard of the fundamentals of statecraft by Ottoman statesmanship and the resultant policy of isolation may be partially accounted for by accidental reasons, by circumstances peculiar to each situation, such as the diversion offered at critical times by Persia — the Empire's most obstinate enemy in the East — internal weakness, the unwarlike disposition of certain sultans and the machinations of rival European diplomats in Constantinople, usually reinforced by handsome presents to the leading women of the sultan's household and the influential ministers. But at the bottom of this attitude of aloofness was the contempt felt by the Ottoman ruling class for all the Christian nations. "What matters it to me," said the great Kiopruli to the French ambassador's messenger sent to announce to him the French victories in Flanders, "whether the Dog worries the Hog or the Hog worries the Dog so my Master's head be but safe." [22] The incident, even if apocryphal, is characteristic of a state of mind compounded of the consciousness of religious and moral superiority and ignorance "of the strength and constitution of other countries." [23] The conviction that the Ottoman army was inherently superior persisted in spite of repeated disastrous proofs to the contrary and the notion that the Empire was the arbiter of Europe was entertained long after it had become a mere pawn. "They compare," says Ricaut, writing toward the close of the seventeenth century, "the Grand Signior to the Lion and the other Kings to little dogs which may serve (as they say) to rouse and discompose the majesty of the lion but can never bite him but with their utmost peril." [24] There is cause to be thankful for the proud insensibility of the Ottoman lion and for his contemptuous aloofness. For the history of Europe might conceivably have taken a different course had he condescended to emerge from his den and take part in the petty

[22] Ricaut, *op. cit.*, Chapter XX.
[23] Ricaut, *op. cit.*, Chapter XXI.
[24] *Ibid.*

squabbles of the Western dogs from the age of Charles V to that of Frederick the Great.

Another aspect of this attitude of aloofness was the Porte's reluctance to establish diplomatic relations with other states. It was not until the reign of Mahmud II in the early nineteenth century that permanent Ottoman embassies were established in European capitals. As for the ambassadors of foreign powers in Constantinople, a rather sharp line of distinction was drawn by Ottoman statesmen between those of permanently friendly powers like France, England and Holland, intercourse with which was confined to trade on the basis of the capitulatory régime, and those of potentially hostile powers like Austria, Venice and Russia, with which a state of war was the normal relationship. The former they treated with courtesy and friendliness but the latter they looked upon with suspicion and treated, whenever they could, with contumely. They regarded them, with considerable justice, as spies supplying their government with information that would prove valuable in the next inevitable war. "You have come," said the Grand Vizier Sokolli to the Venetian ambassador Barbaro who had called on him after the battle of Lepanto, "to see how our courage stands after the destruction of our fleet. Know then that by taking Cyprus from you we have cut off your right arm; whereas by destroying our fleet you have only shaved off our beard. And a beard that has been shaved off grows all the thicker." [25] Moreover, the Ottomans conceived of an ambassador as a hostage "responsible for what is acted by his prince contrary to the capitulations of peace . . . a pawn for the faithful and sincere carriage of his nation." [26] Hence, when war was about to be declared, the ambassador of the hostile power was as a rule incarcerated and sometimes he was even compelled to follow the Ottoman armies "as a barbarous trophy in the time of their prosperous success, and as a means at hand to reconcile and mediate when evil fortune compels them to composition." [27] This absence of diplomatic immunity, involving imprisonment, payment of ransom and

[25] Hammer, *op. cit.*, III: 600.

[26] Ricaut, *op. cit.*, Chapter XIX.

[27] *Ibid.*

the violation of diplomatic correspondence, was also the lot of friendly envoys in time of peace whenever they were suspected or guilty of some unfriendly act.

It is a far cry from this precarious situation of the European ambassadors accredited to the Porte during the days of Ottoman power to the era of the Stratford de Redcliffes, the Ignatieffs and the Bibersteins, the virtual dictators of Ottoman policy during the nineteenth century. But although these earlier ambassadors were much less active than their successors in making history, they have made invaluable contributions to the writing of history. The official and unofficial records of their observations during their residence in Constantinople are by far the most copious and the most reliable sources available to the student of Ottoman history and institutions.

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AN EXAMINATION OF THE HISTORICAL RELIABILITY OF FROISSART'S ACCOUNT OF THE CAMPAIGN AND BATTLE OF CRÉCY

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THE value of the *Chronicles* of Jean Froissart as a source for the history of the fourteenth century, so long accepted unreservedly,[1] has, during the last hundred years, been called into question by several able critics. It has been impugned on various scores; and the author of the *Chronicles* has been accused of superficiality, ignorance of geography and chronology, as well as the more damning historical sins of lack of sincerity, partiality, shallow and erroneous judgments. The historian of the wars of Europe has appeared as the mere jongleur of decadent chivalry. Systematic criticism has come chiefly from France;[2] but English writers on the period have learnt to scrutinize his statements with no less care. This reaction from implicit belief was inevitable; it is surprising only that it was so long delayed, and that the more obviously unsound features in the *Chronicles* were not challenged before. Yet, in certain directions, as will be shown, the reaction has gone too far; and the responsibility for this rests largely with the French critics of Froissart, several of whom were writers whose researches, inspired by a spirit of local patriotism or the zeal to vindicate some venerated name, were, as a consequence, confined to a too circumscribed portion of the *Chronicles*. It is the object of this paper to consider a single

[1] For the high reputation which Froissart enjoyed in the later Middle Ages, see the Prologue of the *Chronicles* of Enguerran de Monstrelet, Froissart's continuator.

[2] See especially the writings of Plaine, Betrandy, A. de le Borderie, Lacabane, and of course the magnificent editions of the *Chronicles* by Kervyn de Lettenhove and Simeon Luce.

aspect of the general question of Froissart's historical reliability, namely, the extent of his partiality to one or the other of the two great antagonists in the Hundred Years' War as it appears in his account of the campaign and battle of Crécy.

Of the four books into which the *Chronicles* of Froissart are divided, the first, which includes the narrative of Crécy, is the one upon which its author lavished most attention. Its three editions or redactions correspond to the three definite periods which may be distinguished in the life of the chronicler, the periods of English, of French and of Burgundian patronage. As is well known, the earlier portions of the first book — from 1327 to about 1356 — are based upon, and often textually borrowed from, the *Vrayes Chroniques* of Jean le Bel, Canon of Liège,[3] the "master of Froissart," as he has been called. Broadly speaking it may be said that, for the whole period from 1327 to 1345, Froissart in his first redaction closely follows Jean le Bel.[4] For the narrative of the years between 1345 and 1356, the relation of Froissart's work to that of Jean le Bel is different; it is, in general, the second redaction rather than the first, which bases its account of the events of these years upon the *Vrayes Chroniques.* This circumstance is explained by the fact that, in the first redaction, these events, involving the honour of the two rival nations, are related upon the authority of English witnesses and from the English point of view; while the Canon of Liège, placed in a French environment, gathered his information from Frenchmen and in his narrative reflects their sympathies.[5] Later, when Froissart, as curé of Estinnes and protégé of Wenceslas of Brabant and Guy of Blois, finds himself in the midst of a French society, he rewrites the first book of his *Chronicles* in accordance with the fresh testimony which he now receives. The work of Jean le Bel, rejected for a large portion of the first redaction between Crécy and Poitiers, at once presents itself as a convenient

[3] For an estimate of the historical value of Jean le Bel, see the edition by Viard and Déprez (Soc. de l'histoire de France), t. I, Introd., *passim.*

[4] See Luce, *Chroniques de J. Froissart* (Soc. de l'histoire de France), Introd., pp. xliii–lxii.

[5] See Luce, t. I, Introd., pp. lvii–lix.

basis for a second version of those battles and the events of the intervening years.

In view of these facts, Crécy is an invaluable touchstone of the whole question of Froissart's partiality, so far as England and France are concerned. His conscious bias has been much exaggerated as a result of a singular misconception. A Picard scholar, Rigollot, who had the distinction of being the first to draw the attention of scholars to the *Amiens MS.*, which represents the second redaction of the first book, on examining the portion which deals with Crécy, perceived that it bore a much closer resemblance — textually as well as in feeling — to the version of Jean le Bel, than did the text printed by Buchon and previous editors.[6] Unfortunately, his investigations were confined to this single point, and he formed the conclusion — a conclusion which more extensive comparisons would at once have shewn to be erroneous — that the manuscript before him, since it was apparently less original than the text of Buchon, represented the earliest redaction of the *Chronicles*; the better known version, less full on many points and marked by obvious English sympathies, being, as he supposed, a later version, made as a result of a changed balance of feeling with regard to the rival nations. At first glance, this explanation seems plausible. "Livré aux intérêts de l'Angleterre," says Rigollot, "présentant son livre à des rois anglais, séjournant tantôt à leur cour, tantôt à Bordeaux, auprès du fameux prince noir, arrivé à l'âge mûr, alors que la candeur de la jeunesse fait place aux préoccupations politiques, Froissart prit à tâche, en écrivant de nouveau sa chronique, de changer tout ce qui, dans celles de Jean le Bel, devait contrarier les maîtres auquels il s'était dévoué." [7] But, thanks to the sagacity of Simeon Luce, we now know that this is not the case; the reverse is the true order of sequence. Before, however, the conclusions of Luce were published, the results of Rigollot's error had been very unfortunate. Several scholars of the highest re-

[6] Rigollot, *Mémoires sur le MS. d'Amiens* (Extr. des Mém. de la soc. des antiquaires de Picardie, III, Amiens, 1840, pp. 131–184). Cf. Luce, I, Introd., pp. lix–lxvii.

[7] Rigollot, *op. cit.*, p. 135.

pute were deceived by his arguments; and upon this misconception Kervyn de Lettenhove founded his edition of the First Book of Froissart.[8]

No less disastrous were the consequences to Froissart's authority. His reputation for impartiality, already assailed, received yet another blow. Critics could point to numerous omissions, as they were held to be, in the second redaction. Was it not clear that the protégé of Philippa and Robert of Namur had deliberately suppressed many passages too favourable to the French arms and generalship? Rigollot himself expresses an opinion which soon became widespread, when he remarks that "les changements faits pour Froissart à son premier travail, loin d'être un homage rendu, après coup, à la vérité, sont au contraire calculés pour l'altérer et pour donner le change à l'opinion sur des faits d'une grande importance historique."[9] In reality, as it is now easy to see, what were thought to be omissions correspond to additions, many of them made, one feels, not with any deliberate intent to place the French in a better light, but merely as a result of further information acquired since the composition of the first redaction. It is one thing to suppress known facts; it is quite another to make additions subsequently learnt, even though the additions should be all of one colour and character and intended to foster one definite impression. The sin against the light is obviously graver in the one case than in the other. When the two versions of Crécy are compared, with a full comprehension of their true relation, there are still omissions of which the least exacting might complain. The catalogue of these, though curtailed, will not lose any of its significance; it will still serve as an index of Froissart's good faith. But the relation of omission and addition is clearly changed, in fact, reversed; and it is distinctly more favourable to Froissart than it was before.

It would have been hard for the most servile flatterer of France to say much that was really creditable to the French at Crécy; but what could be said without deliberately distorting facts, Froissart in his second version has contrived to say. Yet it is rather by what he adds than by what he omits that he has

[8] See Luce, I, Introd., p. lix.

[9] Rigollot, *op. cit.*, p. 135.

succeeded in giving to the *Amiens MS.* its peculiarly French colour.

On at least four salient points, the two versions of the campaign and battle have been said to shew considerable divergences: in their accounts of English depredation in the north of France; in the matter of the resistance offered by the French; in their estimates of strategy and generalship; and finally, in the numbers of the English at Crécy.[10] Let us examine the two narratives, with especial regard to these four points, at the same time controlling them, where possible, by means of other authorities. We shall thus be enabled to form an opinion, not only as to Froissart's sincerity, but also as to his real value in that field which has been regarded as especially his own, the military history of the fourteenth century.

Edward III and the English army landed at Saint-Vaast de la Hougue, July 12, 1346.[11] Was their landing unopposed, as it appears in Froissart's first redaction, or was it, on the contrary, stubbornly contested by the French? The *Amiens MS.* gives a detailed description of a struggle, stern and long, which had to be waged before the invaders could make good their footing upon the soil of France: "Et prendoient li Englez terre à grant meschief; car li Franchois leur estoient au devant, qui lez traioient et berssoient, et en navrèrent de coumencement pluisseurs, ainchois que il pewissent ariver." [12] This testimony is supported by a considerable range of authority; but not, it must be confessed, of the most reliable kind.[13] Whether, if it is not a mere fiction,

[10] Rigollot (*op. cit., passim*), who, however, confines his remarks to the battle and its immediate preliminaries.

[11] Not the 22d, the date given by Froissart, Luce, *op. cit.*, III: 357. For the complete itinerary of the march, see Sir E. Maunde Thompson's edition of Baker of Swinbroke, pp. 252–257.

[12] Luce, III: 359 (*Amiens MS.*).

[13] Chandos Herald (ed. H. O. Cox, Roxburghe Club, 1842); *Valenciennes Chronicle* (printed by K. de Lettenhove, *Oeuvres de Froissart*, IV: 485–586). Bartholomew Burghersh (Murimuth, *Continuatio chronicarum*, ed. Thompson, p. 200) mentions an encounter between Warwick and the French, without, however, connecting it with the landing of the English. Murimuth, p. 199, is explicit to the contrary: "sine resistentia qualicumque." Chandos Herald and the *Valenciennes Chronicle* confirm Froissart's second redaction as to the presence of Robert Bertran at La Hougue. No resistance is mentioned by Baker, p. 79.

Froissart knew the fact at the time of the composition of the first redaction is an interesting, but, because of the dearth of evidence, an unprofitable speculation, in which the *onus probandi*, moreover, wholly rests upon those who would assert that he did.

Philip of Valois, learning of the imminent approach of the English fleet, but ignorant of its precise destination, at once prepared for resistance. If we are to believe the second redaction, his preparations were extensive and systematic. He dispatched troops to all the seaports and larger towns: to Caen he sent Raoul, Count of Eu and Guines and Jean de Melun, Lord of Tankarville; Robert Bertran was deputed to guard the Côtentin; while Godemar du Fay was entrusted with the defence of the seaboard from Harfleur to Calais; and each of these leaders was provided with "grant fuisson de gens d'armes." Robert Bertran had some 2,000 men.[14] Compared with this account that of the first redaction in casual and meager. It mentions only the force sent to Caen; defensive measures on a large scale, one is led to suppose, were not undertaken until it was already too late; and not until the English had got as far as Carentan did the French king bestir himself to summon his allies.[15] There is, however, no reason to doubt on this point the authority of the second redaction; indeed, it seems certain that more or less substantial preparations for resistance were made at an early stage in the campaign.[16]

Froissart's account of the siege and capture of Caen is of singular interest, since it has been made, at a comparatively recent date, the subject of a damaging criticism by an authority

[14] Luce, III: 357 (*Amiens MS.*). See also De Nangis, Cont., II: 196.

[15] Luce, III: 137, 138.

[16] A retinue roll of the men at arms sent to Harfleur and Caen is extant. See Luce, *op. cit.*, III, p. xxxiv, n. 6. Further, we know that in July Philip was sending provisions into Caen (*Les Journaux du trésor de Philip VI de Valois*, No. 1539). His naval preparations, too, were extensive. See letters of Edward III dated 2d January, and 15th March, 1346, in Rymer, *Foedera*, III, Pt. i, pp. 62, 72, 73. *Grandes Chroniques* (V: 451) speaks of the King of France sending to Genoa for boats on which to transport a large army to England. See, also, a fragment from the accounts of the *bailli* of Caen in 1346, relating to his expenses "pour cause de navire de l'armée de la mer," "pour fere devaler les nefs de Caen en la mer," "pour espier le navire d'Angleterre" (British Museum, Addit. Chart. II).

whose competence, in all that concerns the history of Caen, cannot be questioned.[17] The chronicler has, for the most part, borrowed his narrative from that of Jean le Bel. "Sur ce fonds Froissart, d'ailleurs, a, suivant son habitude, brodé des détails dont quelques-uns sont manifestement inexacts. Le brillant chroniqueur a été ici victime de son imagination ou de ses informateurs." [18] On the subject of the resistance offered by the besieged, both writers have fallen into an error of the gravest sort, in their imputation of cowardly behaviour against the citizens of Caen. These men, we are told, sallied forth, in defiance of the instructions of the Constable of France, the Count of Eu and Guines and the Lord of Tankarville, to meet the invader; and then, panic-stricken at the sight of the approaching banners of England, turned in disordered flight. "Si se retraisent cescuns viers leur ville, sans arroi, vosist li connestables ou non." [19] It is, apparently, a pure invention; but it is repeated in the *Amiens MS.*,[20] a fact which we might consider illustrative of the comparative consistency of the two versions in this matter of French resistance, were it not that, knowing how strong were the anti-democratic prejudices of our chronicler, we feel that there was a sufficient inducement for him to retain this passage. The most reliable evidence that we possess, the letters of Michael Northburgh and Bartholomew Burghersh, and the very important authority of an anonymous English chronicler, either contradicts or fails to confirm Froissart and Jean le Bel. Michael of Northburgh's testimony is particularly noteworthy. According to him, "les Fraunceis defenderent le dit pount fortment et à eaux portèrent mult bien." [21]

[17] See Prentout, *Prise de Caen*, (*Extr. des Mém. de l'académie des sciences et belles-lettres de Caen*, 1904). This writer makes the anonymous chronicle, printed by Moisant (*Le Prince Noir en Aquitaine*, pp. 157 ff.), together with the letters of Michael of Northburgh and B. Burghersh, the basis of a new version of the siege and sack of Caen. The result is distinctly unfavourable to Froissart. See especially, Prentout, *op. cit.*, Appendix II, where Froissart's authority for this event is discussed.

[18] Prentout, *op. cit.*, p. 17.

[19] Luce, III: 143.

[20] Luce, III: 373 (*Amiens MS.*).

[21] Michael of Northburgh (Avesbury, *De gestis mirabilibus regis Edwardi Tertii*, ed. Thompson, p. 359). See also Burghersh (Murimuth, p. 202); Fragment of chronicle (Moisant, p. 164). A letter of Edward III

But, valiant as was the French resistance, it was of little avail; the English host swept on, unchecked. Here and there a fortress of exceptional strength might defy all efforts to reduce it; but the country, almost to the walls of Paris, had to yield before the invader.

At Paris lay Philip of Valois, filled with dismay. But mark how different are the accounts of his behaviour which Froissart has given in the two redactions. In the earlier version, we are shewn the tragic spectacle of a shiftless king, abandoning, despite the entreaties of the citizens, his threatened capital. "Quant las gens de Paris veirent le roy leur signeur partir, si furent plus effreet que devant, et vinrent à lui en yaus gettant en genoulz et disant: 'Ha! chiers sires et nobles rois, que volés vous faire? Volés vous ensi laissier et guerpir vostre bonne cité de Paris? Et se sont li ennemi à deux liewes priès: tantost seront en ceste ville, quant il saront que vous en serrés partis. Et nous n'avons ne n'arons qui nous deffendera contre eulx. Sire, voelliés demorer et aidier à garder vostre bonne cité.' Donc respondi li rois et dist: 'Ma bonne gent, ne vous doubtés de riens. Jà li Englès ne vous approceront de plus priès. Je m'en vois jusques à Saint Denis devers mes gens d'armes, car je voel chevaucier contre les Englès et les combaterai, comment qu'il soit.'" Meanwhile, the king of England keeps his state at Poissy, clad in robes of scarlet furred with ermine; for it is the feast of the Assumption of our Lady.[22]

These pictures are much modified in the second redaction: it is another king we see, a king who, fully alive to the peril which threatens his land and people, takes counsel with his prelates and allies and retires to St. Denys only to make it the center whence he may issue writs of summons to Burgundy, to Champagne, to

(Aug. 3, 1346) cited by Henri Denifle (*La désolation des églises, monastères et hôpitaux en France pendant la Guerre de Cent Ans*, II: 37) testifies to the quality of the resistance made by the men of Caen. The English writers are confirmed by the French. See *Grandes Chroniques*, ed. Paulin Paris, V: 453; De Nangis, II: 197; Ric. Le Scot, p. 72; *Chronographia*, II: 224; *Chronique normande*, p. 67.

[22] Luce, III: 149–150; *Valenciennes Chronicle*, K. de Lettenhove, *Oeuvres de Froissart*, IV: 495 gives a similar account.

Artois, and to other parts of his realm.[23] Yet it will be observed that these two versions are not, as regards their essentials, very different. The fundamental facts are the same in both. In estimating their relative accuracy we have to make a choice, not so much between two conflicting sets of statements, as between two entirely different effects. On the whole, other authorities tend to confirm the second redaction. We learn from an eye-witness with the English army, Michael of Northburgh, whose report is one of the most valuable of our authorities for this campaign, what we should never have guessed from Froissart's first redaction or even from the second,[24] that Philip of Valois made genuine, though fruitless, efforts to oppose, by means of a force collected from the neighbouring towns, and, in particular, from Amiens, the rebuilding of the bridge at Poissy by the English.[25]

The army of Edward III now crossed the Somme and traversed Picardy by forced marches. Progress was not easy; the French resisted stoutly, as we can see from Froissart; and engagements took place which Froissart does not mention.[26] Local

[23] Luce, III: 380 (*Amiens MS.*). Also *Grandes Chroniques*, V: 458–459; De Nangis, Cont., 107c.

[24] Froissart says (Luce, III: 149) that the bridge was rebuilt "pour passer son host aisément et sans peril." The episode of the Amienois (borrowed from J. le Bel) is recounted a little later, and not in connection with the Poissy bridge. Also Froissart, 2d red., except that he (Luce, III: 380) definitely mentions the crossing of the English at Poissy, but speaks of no resistance.

[25] Michael of Northburgh's letter in Avesbury, *De Gestis Edwardi*, p. 367: "Et en refesance du vindrent gentz d'armes a graunt nombre od les comunes du pais et de Amyas, bien armez." See also Luce, *op. cit.*, III, p. xl, n. 4; Wynkeley's letter in Murimuth, p. 215; Baker of Swinbroke, p. 81; the fragment of a chronicle in Moisant, p. 170. These authorities are not in agreement as to the number of French slain: Michael of Northburgh, "plus que D"; Wynkeley, "mille vel circiter"; Baker, "trecentis Gallictis peremis." Moisant, p. 170: "quingenta corpora et amplius." But, in any case, the number was large enough to leave no doubt of the quality of the French resistance. Jean le Bel, *op. cit.*, II: 88: "grand foison de bourgoys d'Amiens, à cheval et à pyé, qui s'en aboient au mandement du roy à Parys." But this is after the crossing. Note his severe censures of Philip's inaction, p. 86. Michael of Northburgh (Avesbury, p. 359) says it was the Earl of Northampton who defeated them.

[26] See the affray at Grandvilliers between the English vanguard and the King of Bohemia's men-at-arms. Michael of Northburgh, in Avesbury, p. 368.

forces coöperated with detachments from the main army of France in the endeavour to impede the march of the invaders. Versions of the defence of Oisement, which differ significantly, are given in the two redactions. The first redaction describes the half-hearted resistance of a body of fugitives from the surrounding country, who had fled into the town as a place of refuge.[27] In the later version a force drawn from the neighbourhood, but led by several knights of distinction, marches out to meet the invader, and is beaten only after a desperate struggle. "La y eut grand hustin et dur. Et eurent li Englès une mout fort rencontre, et en y eult pluisseurs navrés et blechiés. Et trop bien s'i portèrent li Franchois. . . ." [28]

French resistance culminated at Blanchetaque, a ford on the Somme, where Edward and his army had to fight their way across the river in the face of strenuous opposition from some 12,000 men, mostly from neighbouring towns, captained by Godemar du Fay, whom Philip of Valois had specially entrusted with the task. Many fine feats of arms were performed on both sides; and the first redaction, in spite of its English sympathies, pays ungrudging tribute to the staunch and prolonged defence that was made. "La commenca un fors hustins, car messires Godemars et li sien deffendoient vassaument le passage." [29] Only in two particulars is the account contained in the *Amiens MS.* markedly different: it mentions a wound received by Godemar du Fay,[30] and omits some phrases describing the disorderly flight of the French.[31]

In general, then, the second redaction brings out somewhat more clearly the resistance offered by the French, a resistance, as we have seen, stubborn throughout and sometimes heroic. Occurrences such as that at St. Lô, when the defenders, seized with panic, fled without awaiting the arrival of the English, were, we may believe, comparatively rare.[32] But the resistance was spo-

[27] Luce, III: 157.

[28] Luce, III: 392 (*Amiens MS.*).

[29] Luce, III: 161.

[30] Luce, III: 161.

[31] "Depuis ne tinrent li François, gaires de conroy et se partirent, qui partirent, qui partir s'en peut . . ." — Luce, *op. cit.*, III: 162.

[32] Luce, III, p. xxxvi, n. 1; also Cotton MS. Cleopatra D. vii, f. 179, printed in Sir E. Maunde Thompson's edition of Baker, p. 253.

radic, unorganized, and, in consequence, unavailing; isolated strongholds alone held out. At Cherbourg, though the town was taken at the first assault, the castle defied its besiegers. Curiously enough, it is the first, not the second, redaction which tells us this.[33] Evidently in this matter at least it would be easy to exaggerate the partiality of Froissart.

Froissart's testimony as to the extent and character of the devastation wrought by the English army in its progress through northern France next demands consideration. Are Froissart's pictures of wholesale pillage and wanton destruction wholly credible? There is every reason, it must be confessed, for thinking so, since they tally only too well with the evidence of other contemporary records, English no less than French. In fact, as a recent writer has remarked, "cette expédition d'Edouard, semblable à un ouragon, sinistre et foudroyant, eut des effets effroyables." [34] No striking differences between the two redactions are perceptible; additions, where they exist in the *Amiens MS.*, are almost all such as might have been introduced by one who, since composing his earlier version, had heard the story over again from fresh witnesses. This is, as we have seen, what actually happened; but, at times, Froissart's consistency is such that one could almost believe these new witnesses to have been of the same party as those who had provided material for the first redaction. Thus the sack of Barfleur, Cherbourg, Valoques, and Carentan is described by both redactions in substantially the same terms; the only significant feature, if it can be regarded as such, is the omission from the later account of the qualification "sans ardoir," originally appended to the statement, "Barflues fut prise et reubée." [35] The second redaction is here, as often, the more accurate. The English *burnt* Barfleur.[36] The wholesale

[33] "Si en ardirent et reubèrent une partie, mès dedens le chastiel ne peurent il entrer, car il le trouvèrent trop fort et bien garni de gens d'armes." — Luce, III: 134–135. Also Michael of Northburgh (Avesbury, p. 359).

[34] Denifle, *op. cit.*, II: 35.

[35] Luce, III: 134–136; 360–362 (*Amiens MS.*). It is instructive to note that, although in this part of his narrative Froissart textually follows Jean le Bel, this qualification is his own. Cf. Jean le Bel, II: 72.

[36] Avesbury, p. 358, and the fragment of an anonymous chronicle printed by Moisant, *Le Prince Noir en Aquitaine*, p. 160.

pillage, which marked this first portion of the English march, is more fully brought out in the third redaction than in either of the two earlier ones; and an inspection of English authorities assures us that it has not been exaggerated.[37]

Only in the accounts of the journey through the Vimeu do we notice any serious discrepancies. From this point, we may believe, with Rigollot, that the basis of the *Amiens MS.* is furnished by the narrative of Jean le Bel; from this point the first redaction, at least for this campaign, becomes comparatively independent of the chronicler of Liège. A striking illustration of these conclusions is provided by an account of the burning of the town and abbey of Mareuil, which is found only in the *Amiens MS.*;[38] it is borrowed almost textually from Jean le Bel.[39] Significant, too, is the omission of these facts from the *Rome MS.*, a version, in general, still more hostile to England than the second redaction. We cannot suppose that, in this latest version of the first book, the chronicler had felt any reluctance to narrate circumstances unfavourable to the English; indeed, he has elsewhere added certain details of English depredation[40] which find no mention in the earlier redactions, or in Jean le Bel. The explanation of this apparent inconsistency is that Froissart's paramount desire, in his third redaction, was to efface all traces of his debt to the author of the *Vrayes Chroniques*.[41]

It is certain that, during the course of this memorable march through Northern France, Edward III from time to time made efforts to limit the extent of the devastation. It is one of the few features of the journey really creditable to the English king; but it is creditable rather to his generalship than to his clemency. Occasionally, perhaps, he was impelled by humane sentiments. When he hanged twenty of his soldiery, who had fired the abbey of St. Lucien, he may have been prompted by something more than

[37] Luce, III: 361–363 (*Rome MS.*). Michael of Northburgh (Avesbury, p. 359) says the English fired the country for two or three leagues inland. The Cotton MS. Cleopatra D. vii, fol. 179 (Baker, p. 253) testifies to the ravages committed around Carentan.

[38] Luce, III: 392 (*Amiens MS.*).

[39] Jean le Bel, II: 95.

[40] Luce, III: 391 (*Rome MS.*).

[41] As Luce has remarked, I, Introd., p. lxxiv.

policy alone.[42] But, as a rule, his motives were motives of policy. When the host lay at Airaines, he commanded all, on pain of hanging, to do no hurt to the town by burning or otherwise, "car il se volait la tenir un jour ou deux, et avoir avis et conseil par quel pas il poroit la rivière de Somme passer mieulx à sen aise." [43] At Caen, when the king, angered by the resistance which he there encountered, threatened to put all the inhabitants to the sword, Godfrey of Harcourt remonstrated with him: "Vous avez encores à faire un moult grant voiage, ançois que vous soiiés devant Calais ou vous en tirés à venir. Et si a encore dedens ceste ville grant fuison de peuple qui se deffenderont en leurs hostelz et leur maisons, s'on leur keurt seure, et vous poroitz trop grandement couster de vos gens, ançois que la ville fust essillie par quoi vostre voiages se poroit desrompre." [44] The incident is probably fabulous,[45] but it is, one feels, very characteristic; and other authorities confirm this view of Edward's motives. At Carentan, says one, he issued the strictest injunctions that no food was to be taken more than sufficed for each man's need.[46] According to the same authority, the king had warned his troops at the outset of the campaign to refrain from depredation and the molestation of civilians.[47]

We have seen how, in one instance at least, the two earlier redactions convey different impressions of the French king's military capacity; in the narrative of the battle, the first redaction

[42] Luce, III: 151; *Idem, Amiens MS.*, p. 384.

[43] Luce, III: 154. Also *Amiens MS.*, p. 387.

[44] Luce, III: 145, 146.

[45] See Prentout, *La Prise de Caen*, pp. 59–60.

[46] Fragment of a chronicle printed by Moisant, *Le Prince Noir en Aquitaine*, p. 162: "Ex parte dicti Regis Anglorum, strictissime fuerat imperatum ne aliquis de cetero victualia plusquam suo usui sufficerent presumeret dissipare, sub pena et pro mercede superius annotatorum."

[47] Ibid., p. 160: "Rex insuper Anglorum mitissimus, angustiis miserabilis ipsius patrie populi multipliciter compaciens, ubique per suum exercitum edictum faciebat, ut nullus villas aut maniera incendere, ecclesias vel loca sacra depredari, senibus, parvulis aut mulieribus quibuscumque regni sui Francie malum seu molestiam inferre presumeret, seu quibuscumque personis aliis, nisi viribus instarent, malefacerent quovismodo, sub pena vite membrorum. De cetero iubebat quodquod, si aliquis in premisso seu premissorum aliquo criminosum et actu deprehensum regi adduceret, quadraginta solidos pro merito reportaret."

becomes still less favourable to Philip of Valois. On the other hand, that consistency of which Froissart is capable, when he chooses, is manifest in his treatment of Edward III. The second redaction is the only one which mentions the English king's wise command that no man should, without his permission, leave the ranks for the purpose of despoiling the dead.[48] Clearly, Froissart did not hesitate to introduce, even into the version favourable to France, a fact so creditable to the generalship of the king of England, doubtless learnt since the composition of the first redaction. Let us examine the two accounts of the battle, so far as the differences which they present might be thought to affect the military reputation of either side.

Nothing throws more light upon the reasons for the English success at Crécy, nothing brings out more clearly the superiority of English leadership, than the immediate preliminaries of the battle. Both pursuers and pursued had accomplished long journeys within a short space of time. The English, as we have seen, had had to overcome considerable resistance at several points before their way lay clear. But, whereas the English wisely spent the few hours before the battle in much needed rests, the opposing army consisted of men utterly wearied with incessant pursuit. Froissart does not tell us in his second redaction how the English, after the king had disposed them in order of battle, "leur bacinés et leurs ars devant yaus, en yaus reposent, pour estre plus fresch et plus nouvel, quant leur ennemi venroient." [49] He does not tell us that the French army, straggling along the road to Crécy, was in such confusion and disorder that it was impossible for those who witnessed the scenes to understand what was taking place.[50] Nor does he describe for us here the king of France, seized, when he views the hostile host, with ungovernable rage, losing all self-control, and crying out to his marshals: "Faites passer nos Geneuvis devant et commencier la bataille, ou nom de Dieu et de monsigneur saint Denis!" [51]

[48] Luce, III: 404 (*Amiens MS.*). [49] Luce, III: 170.

[50] Luce, III: 174; also "sans arroy et sans ordenance" (*ibid.*). Jean le Bel (ed. Viard and Déprez, II: 102) is still more damning: "ainsy chevauchant par orgueil et envie, sans ordonnance, l'ung devant l'autre."

[51] Luce, III: 175.

These unhappy men complained of fatigue and begged leave to rest a while; but the French leaders were inexorable, and the count of Alençon passionately denounced the Genoese: "On se doit bien cargier de tel ribaudaille qui fallent au plus grant besoing." [52] We hear nothing of these things in the *Amiens MS.* It is true that both versions bear witness how the Genoese, when cowed and beaten they took to flight, were ridden down by the resentful or impatient horsemen of France; but with what differences of circumstance. According to the first redaction, Philip of Valois cried out: "Or tos, or tos tués toute ceste ribaudaille: il nous ensonnient et tiennent le voie sans raison"; whereupon the horsemen rode them down.[53] In the *Amiens MS.* this harsh command is suppressed, and the riding down is made to appear not a deliberate act, but the unavoidable consequence of the French advance.[54] This is a typical instance of the way in which Froissart, while retaining the fundamental facts, has changed the colour and character of an incident. Another instance is afforded if we compare the passages in the two redactions, which describe the episode of the foot-soldiers who went in among the confused and struggling mass of French horsemen, doing deadly work with their knives.[55] The *Amiens MS.* relates this episode with considerably more emphasis, and identifies them as English men-at-arms, a serious imputation against that class as a whole.[56]

From what has been said, it will be clear that, viewed through the medium of either version, the case for the French king's military capacity is no strong one. In the second redaction, Froissart could do little to improve it; but that little he has done. The supreme act of folly on the part of Philip lay in the rash haste

[52] Luce, III: 175–176.

[53] Luce, III: 177. Luce (IV: i) prints a document which asserts, as a matter of common knowledge, that the Genoese were traitors, suborned by English gold.

[54] Luce, III: 417 (*Amiens MS.*). Baker (p. 83) implicitly confirms this: "balistarios ad numerum septum millenariorum inter ipsos et Anglicos situatos sub pedibus equorum calcaverunt prostratos, impetuose festinantes in Anglicos suas ostentate virtutes."

[55] Luce, III: 177. In another MS. of the first redaction, they are correctly described as Welshmen (Luce, III: 417).

[56] Luce, III: 417 (*Amiens MS.*).

with which, according to the earlier version, he began the battle, precipitating against the compact and well-dispositioned forces of the English an army of stragglers, weary with the long day's pursuit. For the successive disasters that followed, Philip, posted in the rear of the French army, cannot be held accountable; the second redaction acquits him of responsibility for the initial blunder.[57] He listens to the wise counsel of the "lord of Baseilles,"[58] who advises him to halt for the day; he approves and tries to put it into execution, sending orders both to the van and to the rear. But he "had failed to take into account the rashness and insubordination of a feudal host";[59] and the great French army, deaf to his commands, every man filled with a desire to be before his fellows in the field, moves on to destruction.[60] Thus far the versions are in agreement; and thus far, reading either version, we should come to the conclusion that the disobedience of the French troops was at the root of the matter. But when by the first redaction we are told of the rash command, issued in a momentary fit of passion, Philip of Valois at once relinquishes, in our eyes, his last slight claim to generalship. Froissart knows this, and, in his later redaction, by expunging this passage, by still further insisting upon the disobedience of the French host, strives to repair the injury done to a reputation.[61]

On the subject of the numbers of the English forces engaged at Crécy, there has been among modern authorities considerable difference of opinion. Froissart's figures, rejected absolutely by one writer, have by another been followed with uncritical servility. At first sight the numbers which the chronicler gives seem little compatible. The *Amiens MS.* contains an estimate markedly higher than that of the first redaction, a fact which has been thought due to Froissart's partiality for the English in the earlier version.[62] More recent investigations, however, based upon the

[57] Cf. Rigollot, *op. cit.*, p. 154.

[58] Henri le Moine of Bâle. (See Bibl. de l'École des Chartes, t. LXVII, p. 489.)

[59] Oman, *Art of War in the Middle Ages*, 2d ed., II: 139.

[60] Luce, III: 172–173, 413 (*Amiens MS.*).

[61] Luce, III: 423, 420 (*Amiens MS.*). Cf. pp. 182–183 and 177–179, first redaction.

[62] Rigollot, *op. cit.*, p. 148.

accounts of Walter Wettewang, the treasurer of the household,[63] made up while the army lay before Calais, taken in conjunction with the figures given in the muster-rolls of the men enlisted at the outset of the expedition, lead us to a very different conclusion. Froissart's first redaction gives 8,200 as the total for the entire Crécy army, a figure which even the most relentless critics of medieval chroniclers' figures must regard as sufficiently conservative. The *Amiens MS.* puts the total at 15,000 or 14,900, an estimate still modest, in comparison with those of other chroniclers, and not at all out of the range of probability. Indeed, it agrees well enough with the total of 14,000 (more or less) reached by Dr. J. E. Morris,[64] whose calculations from the materials provided by General Wrottesley appear eminently reasonable. The more cautious estimate of 10,000 or less, made from the same materials by Sir James Ramsay,[65] another authority of weight on this subject, suggests a comparison with the 8,200 of Froissart's original redaction. If we may trust the calculations of Dr. Morris, the Crécy army must have consisted of something like 600 knights, 1,800 esquires, and 1,600 *armati* or *hobelarii*, giving us a rough total of 4,000 mounted men. This total, as Dr. Morris has pointed out, tallies quite well with the figures given in the second and third redactions, i.e. 3,900 or 4,000;[66] while the total of knights and esquires, 2,400, is not incompatible with the estimate of the first redaction, i.e. 2,000.[67] It is possible that Froissart includes in this last figure only the knights and esquires, and that the 3,900 or 4,000 of the later redactions is a more comprehensive figure, covering *armati* or *hobelarii* as well as the heavy cavalry. On the other hand, the figure of the second redaction is probably copied from Jean le Bel.[68] Here, as in a multitude of similar instances, if there is inaccuracy

[63] These are printed by General Wrottesley, *Crécy and Calais*, pp. 193–204. This editor, however, has not made adequate use of the materials he has provided.

[64] See J. E. Morris in *English Historical Review*, XIV: 766.

[65] See Ramsay in *English Historical Review*, XXIX: 224. Cf. Ramsay, *The Genesis of Lancaster*, I: 319.

[66] Luce, III: 405–408 (*Amiens* and *Rome MSS.*).

[67] Luce, III: 168–170.

[68] Jean le Bel, II: 105, 106.

or exaggeration, it is impossible to assess the exact amount of Froissart's responsibility; and therefore ridiculous to generalize as to the part which bias may have played in leading him to make erroneous statements. If, as Rigollot believed, the version which we now know as the first had really been the second, the case against Froissart would have been serious, although by no means damning. As it is, although the figures of the second redaction are higher than those of the first, they are nevertheless, as we have seen, near enough to the best modern computations to afford good reason for believing them to be honest estimates — whether borrowed from Jean le Bel or reached by Froissart independently — based upon tolerably sound information.

The foregoing study can have no claim to be exhaustive. But enough has been said, it is hoped, to show that the charge of wilful and irresponsible perversion of truth cannot be substantiated. A partisan Froissart undoubtedly was; but that was inevitable. As a native of Hainault, he occupied a position which in a more fortunate age might have been one of comparative neutrality. He might have risen above partisan prejudices dictated by ephemeral circumstances and attained a high level of impartiality. But in the fourteenth century such a position was out of the question, and what was gained by the chronicler's initial detachment from a national cause was more than counterbalanced by the additional risk to which he was exposed of becoming merely subservient to a powerful patron. Yet even as it was, he escaped the insularity of Baker and Walsingham and the official patriotism of the *Grandes Chroniques;* and however strong his sympathies for the patrons of the present hour may have been, our comparative study of the different versions of the Crécy campaign will have taught us nothing if it has not taught us that there are very definite limits to the degree in which such sympathies have led Froissart to falsify the facts of history.

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THE INFLUENCE OF MARTIN VAN BUREN ON THE CAREER AND ACTS OF ANDREW JACKSON

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FROM the closeness of the relationship of such a successful politician as Martin Van Buren to the administration often known as the "reign of Andrew Jackson" arises a very natural question regarding the influence of the politician upon the president. This paper is an attempt to answer that question. Any answer must be unsatisfactory because the most vital phases of the influences between men are those which leave few records. From memoirs, biographies and letters, what follows has been written.

The written record of the fact that Jackson had come to the attention of Van Buren begins with the statement that in 1812 Aaron Burr had told him that Jackson was a good military man.[1] In 1815 Van Buren drew up the resolutions in the New York state legislature commending Jackson.[2] About the same time he wrote to General Winfield Scott mentioning Jackson favorably.[3] In the winter of 1815–16 the two men met for the first time in Washington, where Jackson had been called as a result of his Seminole campaign.[4] A few years later Jackson made an unfavorable impression on Van Buren, during the former's visit to New York. The freedom of the city had been given to the general. Tammany gave him a great dinner at which, to the dismay of all Crawford supporters, of whom Van Buren was one of the chief, he toasted DeWitt Clinton, the leader of the op-

[1] Parton, *Life of Andrew Jackson*, I, 361.
[2] *Ibid.*, I, 257.
[3] *Calendar of the Van Buren Papers*, March 16, 1815.
[4] Van Buren, *Autobiography*, p. 232.

posing faction.[5] In 1823 Jackson took his seat in the Senate where he became better acquainted with the New Yorker.[6] Their seats were near together and many conversations between Jackson and his southern friends took place within Van Buren's hearing. The two senators were by no means at all times of the same political views, though common opposition to Adams probably drew them closer together than would otherwise have been the case.

Though the defeat of Crawford and the success of the Clintonians had been blows at the prestige of the Albany Regency,[7] that organization built up by Van Buren in New York politics, its leader was recognized as a power to be reckoned with. This is shown by the attempts made to shelve Van Buren by placing him on the Supreme Court as early as 1823.[8] The attempt however fell through. Van Buren was left without a candidate to support. By June, 1825, he had decided that Jackson was his man.[9] This decision was quite recent, for but a short time before, the *Albany Argus*, a Van Buren paper, had declared that "Jackson has not a single feeling in common with the Republican party, and makes the merit of desiring the total extinction of it." [10] It must have been obvious that Jackson was the most likely candidate. One difficulty alone stood in Van Buren's way. Support of Jackson implied support of Calhoun who was Van Buren's rival for political prestige. Van Buren even thought of running Clinton for vice-president instead of Calhoun. Balch is quoted some years later as saying that it was due to his influence that Van Buren gave up this idea, the argument being that if Clinton were elected vice-president, Jackson was almost sure to make Calhoun secretary

[5] *Ibid.*, p. 253; Parton, *op. cit.*, II, 561; Bassett, *Life of Andrew Jackson*, I, 287.

[6] Van Buren, *Autobiography*, p. 232; Bassett, *op. cit.*, I, 344.

[7] Van Buren, *Autobiography*, pp. 142, 145, 149, 233. Weed, *Autobiography*, pp. 107–116; Parton, *op. cit.*, II, 664; III, 26; King (ed.), *Writings of Rufus King*, VI, 504, 509–510.

[8] King (ed.), *Writings*, VI, 510, 511, 512; Van Buren, *Autobiography*, pp. 140–141; *Calendar of Van Buren Papers*, March 17, 21, 25; April 4, 1823.

[9] Van Buren, *Autobiography*, pp. 198–199.

[10] Shepard, *Martin Van Buren*, p. 119.

of state, which would ruin Van Buren's hopes forever.[11] At any rate Van Buren's hesitancy in supporting Calhoun was overcome, and late in 1827 all the Van Buren papers came out together for Jackson. "The effect," says Hammond, "was prodigious." [12]

Van Buren is emphatic in his statement that between the time of Jackson's retirement from the Senate and the day that he himself became secretary of state, there was no personal intercourse between them, nor any communication except of a formal character.[13] This does not mean of course that Van Buren was not interested in the election. Though the exact course followed by the Jackson organization has never been traced in detail, we know that Van Buren took a trip through Virginia, North and South Carolina with C. C. Cambreleng in 1827. "They are generally understood to have been electioneering," wrote J. Q. Adams, "and Van Buren is now the great electioneering manager for General Jackson as he was before the last election for Mr. Crawford. . . . Van Buren has now every prospect of success in his present movements." [14] The same year Eaton traveled as far north as Pennsylvania [15] and probably to New York to consult with Van Buren. The following summer Van Buren wrote to his friend, J. A. Hamilton: "I returned on Thursday from my western excursion. It has been very pleasant, and I hope politically speaking, has been very profitable. We shall beat them greatly." [16] At Van Buren's request, Hamilton also wrote letters concerning Jackson's personal character.[17] One of Van Buren's suggestions regarding such a letter which indicates that he was not very well acquainted with Jackson, reads: "Does the old gentleman have prayers in his own house? If so, mention it modestly." Van Buren insisted that his own name should not be mentioned since the letter might get into

[11] Parton, *op. cit.*, III, 132–133 note.
[12] Hammond, *Political History of the State of New York*, II, 259.
[13] Van Buren, *Autobiography*, p. 243.
[14] Adams, J. Q., *Memoirs*, VII, 272, May 12, 1827.
[15] Binns, *Recollections of John Binns*, p. 253.
[16] Hamilton, *Reminiscences of J. A. Hamilton*, p. 78. August 25, 1828.
[17] *Ibid.*, pp. 75, 76, 79.

print.[18] Hamilton attended the celebration on the anniversary of the battle of New Orleans in 1828, as the representative of the city of New York. On December 24, 1827, Hamilton was received at the Hermitage by the general who seems to have played a passive part in the election. This inactivity is shown by the conversation concerning Van Buren as reported by Hamilton. This conversation also reveals the limited acquaintance between the general and his future secretary of state. Jackson stated that he had heard much that was unfavorable to Van Buren. In reply, Hamilton said that he had known Van Buren since well before 1812, and that he was a careful and useful supporter of the government. Van Buren's reputed cunning was mentioned. Hamilton said that he had not observed anything of the kind; that Van Buren was sagacious and cautious, industrious and successful.[19]

The election over, the first question to be decided was the make-up of the cabinet. Van Buren's own place was determined quite early. Hammond says that a chosen few in Albany were in the secret as early as the summer of 1828.[20] Circumstances considered, this smacks of well-founded surmise rather than actual knowledge. It is hard to imagine a cabinet in which Van Buren had no place. Clay among others says that Van Buren from the first had run upon all tickets for the State Department.[21] As to the other appointments, there was considerable doubt. J. A. Hamilton wrote on February 17, 1829, that nothing was decided beyond Van Buren for secretary of state and Eaton for secretary of war.[22] In fact Jackson offered Van Buren the secretaryship of the State Department, February 15, and the latter's acceptance was received in Washington on the 25th.[23] The other cabinet appointments were known to Webster and

[18] *Ibid.*, p. 79. Letters of September 6 and 26, 1828. See also *Calendar of Van Buren Papers*, Van Buren to C. C. Cambreleng, September 18, 1828.

[19] Hamilton, *Reminiscences*, Chapter IV.

[20] Hammond, *Political History*, II, 286.

[21] Clay, *Private Correspondence*, IV, 222.

[22] Hamilton, *Reminiscences*, p. 102.

[23] *Calendar of Van Buren Papers*, February 15, 1829; February 25, 1829; Hamilton, *Reminiscences*, p. 99.

·Francis Brooke at least as early as the 23d.[24] The list was published in the *Telegraph* of February 26, 1829.[25]

Van Buren had no part in the cabinet appointments. He was much disappointed in the selection, Ingham being the only appointee whom he had heard proposed. He wrote in his *Autobiography* some years later: "It was besides not in my power to regard some of them, . . . as well adapted to a satisfactory performance of the duties to which they have been appointed." [26] The public was also unfavorably impressed. It was recognized, however, that by the very weakness of the cabinet, Van Buren's · influence and prestige were increased. Hamilton said that this cabinet was the most unintellectual which the country had ever had.[27] Van Buren, according to the opinion of J. Q. Adams, was the strongest man in the administration.[28] In the eyes of Cooper of South Carolina, the new secretary was now the 'master-mover,' [29] while Francis Brooke wrote Clay that Jackson, on account of the weakness of the cabinet, must put himself in the hands of the secretary of state who would be *de facto* president.[30]

Van Buren, apparently, had nothing to do with the inaugural address. The original draft was drawn up at the Hermitage by Jackson himself.[31] Though the general impression then prevailed that Jackson had not the literary ability to write such a paper as appeared in print, the most recent opinion, as expressed by Mr. Bassett in his *Life of Andrew Jackson,* is that Jackson had more ability along this line than he has been given credit for. Adams thought that the paper was by Henry Lee,[32] while J. A. Hamilton was convinced that, although the thoughts were Jackson's, the words were those of Lewis and Donelson. Hamil-

[24] Clay, *Private Correspondence,* IV, 222; Van Tyne (ed.), *Letters of Daniel Webster*, p. 141.

[25] Parton, *op. cit.*, II, 174.

[26] Van Buren, *Autobiography,* p. 231.

[27] Hamilton, *Reminiscences*, p. 215.

[28] Adams, J. Q., *Memoirs*, VIII, 129.

[29] Bassett, *op. cit.*, II, 418.

[30] Clay, *Private Correspondence*, IV, 222–223.

[31] Bassett, *op. cit.*, II, 424–431.

[32] *Ibid.*, II, 431.

ton himself claimed to have given advice regarding the paper.[33] The fair conclusion seems to be that Jackson had as much to do with his inaugural address as do most presidents.

Late in March Van Buren arrived in Washington. In the interval his friend Hamilton had acted as secretary of state. The immediate problem as far as Van Buren was concerned was diplomatic appointments. Already, much to his annoyance, the mission to England had been offered to Tazewell and the mission to France to Livingston. He was relieved when circumstances led them to refuse the appointments. Van Buren tried to rid the cabinet of Berrien by offering him the English mission, but the attempt failed.[34] Jackson by this time had been induced to follow Van Buren's advice, and accordingly Rives was sent to Spain, Preble to the Netherlands, and John Randolph to Russia.[35]

The patronage was of great and immediate interest. A clean sweep was everywhere expected. It never came, but there were sufficient removals to cause considerable discontent. Van Buren in all likelihood exercised a restraining hand in the distribution of the patronage. According to his own statement he submitted to Jackson the adverse views in their strongest aspect. In addition he sent to Jackson letters from his correspondents giving various views on the question.[36] Van Buren was not able to prevent the appointment of Samuel Swartwout to the collectorship of the port of New York, though he strongly protested Jackson. Of Swartwout, Cambreleng wrote, April 28, 1829, "if our Collector is not a defaulter in four years, I'll swallow the Treasury if it was all coined in coppers." So annoyed was Van Buren that he even considered resigning.[37] To soothe his injured feelings, Jackson appointed J. A. Hamilton district attorney for the southern district of New York, a blundering bit of politics which Van Buren expected to have difficulty in justifying.[38] Swartwout did default before many years had passed.

[33] Hamilton, *Reminiscences*, p. 104.
[34] Van Buren, *Autobiography*, pp. 257, 216.
[35] *Ibid.*, pp. 257, 259–260.
[36] *Ibid.*, pp. 245–248.
[37] Van Buren, *Autobiography*, p. 266.
[38] *Ibid.*, pp. 262, 265, 268 note.

It is apparent that up to this time the relations between the two men had not been very intimate. Two things contributed to draw them closer together, the Eaton affair and the decline of Calhoun in Jackson's estimation. The first is too well known to need comment. And as to the second, a series of events brought about a change of Jackson's opinion of Calhoun. Calhoun's friends had early attempted to prevent the appointment of Eaton to the War Department. Again, Calhoun's attitude in the Eaton affair, and finally the publication of the fact that Calhoun had opposed Jackson at the time of the Seminole controversy, caused a definite breach between the president and the vice-president.

The effect of all this was to put Van Buren forward as presidential candidate to succeed Jackson. As early as 1824 the *New York American* remarked that the real question was who should be president after March 4, 1833, suggesting that it was time for New York to place one of her native sons in the office and that Van Buren was the strongest prospective candidate.[39] It was expected that Jackson would retire after one term of office. Indeed his health was commonly supposed to be such that it was possible that he would not live through his term of office. Mr. William E. Dodd has recently expressed the opinion that this rumor of ill-health was purposely circulated by Jackson. I have found no evidence which would indicate this to be the case. In fact Jackson wrote a letter to Judge Overton of Tennessee in December, 1829, at the request of Lewis, who feared lest Jackson should die before his successor should be chosen, definitely pronouncing in favor of Van Buren.[40] The final difficulties between Jackson and Calhoun did not become public until the spring of 1831. Van Buren with his usual skill had scrupulously avoided implicating himself in the affair. He refused to read a letter from Calhoun to Jackson, saying that he wished to be able to say that he knew nothing of the affair since he was sure to be blamed for the breach between the president and the vice-president.[41] J. A. Hamilton wrote in 1831 that

[39] Parton, *op. cit.*, III, 32.

[40] Shepard, *Martin Van Buren*, p. 189.

[41] *Ibid.*, p. 187.

until 1830 Van Buren knew nothing of the famous Forsythe letter which brought about the trouble.[42] To a suspicious mind, it seems peculiar that a matter of such importance should not have been communicated by Hamilton, who had the information in 1828, to his close friend Van Buren.

Very definite attempts were made to implicate Van Buren in this affair. Benton says that Calhoun had planned in the winter of 1830–31 to have the *United States Telegraph* and a group of Republican papers print the Jackson-Calhoun correspondence simultaneously, charging Van Buren with intrigue against the vice-president. It was expected that the indignation against Van Buren would be so great that even Jackson could not save him. The plot became known, says Benton, and Jackson had his henchmen, Barry and Kendall, establish the *Globe* in order to push his own reëlection.[43] Duff Green and John Tyler [44] both attributed the founding of the *Globe* to Van Buren. Amos Kendall, however, says that both Green and Benton were wrong, without telling us his own version.[45] In all probability Kendall himself played no small part in the founding of the paper.

This factionalism was too much for the cabinet. Van Buren had a hand in the dissolution. The burden of carrying Eaton had become too great.[46] Van Buren himself decided to resign and wrote to Livingston asking him to come to Washington with the utmost secrecy and despatch.[47] With great difficulty Jackson was persuaded to countenance the resignation. "Never, Sir!" Jackson said, "even you know little of Andrew Jackson if you suppose him capable of consenting to such a humiliation of his friend by his enemies." [48] Convinced of the wisdom of Van Buren's course, Jackson allowed him to resign. The dissolution of the cabinet followed, Eaton giving in his resignation imme-

[42] *Calendar Van Buren Papers*, March 6, 1831. See also Parton, *op. cit.*, III, 310 ff.

[43] Benton, *Thirty Years' View*, I, 129.

[44] Tyler, *Letters and Times of the Tylers*, I, 426–427.

[45] Kendall, *Autobiography*, p. 374.

[46] Bassett, *op. cit.*, II, 520–522.

[47] Hunt, *Life of Edward Livingston*, pp. 356–357; *Cal. Van Buren Papers*, April 9, 1831.

[48] Van Buren, *Autobiography*, p. 403.

diately since he knew himself to be a cause of difficulty.[49] Van Buren put his resignation frankly on the ground of his own political aspirations, that he did not feel it possible to remain in the cabinet unless he renounced his own chances for the presidency.[50]

During the two years that Van Buren had been in the cabinet, his relations with the president had been very close. Their consultations were frequent. They rode together almost daily, such occasions being used by Van Buren to approach Jackson concerning the most delicate matters.[51] From the occasional glimpses of such meetings which we get in Van Buren's *Autobiography*, it is evident that many important discussions took place.

Let us see what Jackson had said in his inaugural upon issues which later loomed large. He failed to mention the Bank, though later in writing to Polk he claimed to have done so in a preliminary draft.[52] Of internal improvements, he said: "Internal improvements and the diffusion of knowledge, so far as they can be promoted by the constitutional acts of the Federal Government are of high importance." As to the rights of the separate states, he hoped "to be animated by a proper respect for those sovereign members of our Union, taking care not to confound the powers which they have reserved to themselves with those they have granted to the Confederacy." He intended to treat the Indians liberally.[53] The paragraph relating to 'reform' was perhaps the only part of the inaugural which could be considered aggressive. Nor can one tell from Jackson's previous attitude on the tariff and internal improvements, what his policy as president was likely to be.

The question of internal improvements came up early. In the first draft of the inaugural address Jackson had said that internal improvements, when not entirely local in character, should

[49] Van Buren, *Autobiography*, p. 406.

[50] *Ibid.*, p. 407; Shepard, p. 195; *Cal. Van Buren Papers*, April 11, 1831; Hunt, *Life of Edward Livingston*, p. 358.

[51] Van Buren, *Autobiography*, pp. 321, 402.

[52] Bassett, *op. cit.*, II, 430, 592.

[53] Richardson, *Messages and Papers of the Presidents*, II, 437.

be built by the national government.[54] Van Buren did not believe that it was constitutional for the Federal government to undertake them.[55] In 1825 he had introduced into the Senate a resolution that Congress did not have the power to make roads and canals within the states.[56] We have Van Buren's own statement that he convinced the president of the unconstitutionality of internal improvements and of the necessity of halting the tendency to speculation.[57] Jackson vetoed the Maysville Road Bill May 27, 1830, and thus challenged the principle of internal improvements.[58] The defeat of the bill was attributed to Van Buren although during the period when the bill was being considered in Congress, his silence was interpreted as opposition to veto. Some considered the veto a shrewd political move on the part of the secretary.[59] The veto won rather wide approval.[60] On the same subject of internal improvements, Van Buren wrote some corrections and additions to the president's views on the Lighthouse and the Louisville and Portland Canal bills which were incorporated in the president's second annual message of December 6, 1830.[61]

When Van Buren left the cabinet in the summer of 1831, he appeared to many as a very astute and successful politician. He was clearly a candidate for the presidency — whether in 1832 or 1836 was not entirely clear. Van Buren was urging Jackson to become a candidate for another term, possibly because he was not sure of his own strength or possibly because Jackson's mind was already made up to run. Webster wrote to Clay April 18, 1830, that the president meant to be reëlected. "Seeing this," wrote the senator from Massachusetts, "Van Buren has been endeavoring to make a merit of persuading him to do

[54] Bassett, *op. cit.*, II, 483.

[55] *Congressional Debates*, 18th Cong., 1st Sess., p. 134.

[56] *Ibid.*, 19th Cong., 1st Sess., p. 20; Van Buren, *Autobiography*, pp. 317–319.

[57] Van Buren, *Autobiography*, pp. 319–321.

[58] Richardson, *Messages and Papers*, II, 483–493.

[59] Bassett, *op. cit.*, II, 488–489.

[60] *Cal. Van Buren Papers*, Letters June 6 and 8, 1830.

[61] *Ibid.*, Nov. ?, 1830; December 6, 1830; Richardson, *Messages and Papers*, II, 508.

so on the ground of its being necessary to hold the party together." [62] Webster himself had high hopes, in case Jackson should be prevented from being a candidate, that he could defeat both Van Buren and Calhoun. The ill-health of Jackson, doubtless exaggerated, was always a factor to be considered. Van Buren's friend, Hamilton, regarded his resignation from the cabinet as a master political stroke. It would increase his hold upon the public and disarm his enemies.[63]

After his retirement from the cabinet Van Buren kept up his contacts with the president. The latter asked his advice on the subject of the new cabinet and also upon the next message.[64] What was Van Buren to do in the future? McLane came home from London to become secretary of the treasury. Van Buren went to the Court of Saint James, giving up in his own mind, according to his *Autobiography*, his chance of reaching the presidency.[65] The Senate changed the whole situation by rejecting Van Buren's nomination on January 25, 1832.

More than anything else the Senate's rejection of Van Buren made him a vice-presidential candidate. As Benton said to Senator Moore of Alabama, "You have broken a minister and elected a vice-president. The people will see in it but a combination of rivals against a competitor." [66] Lord Auckland remarked to Van Buren, "It is an advantage to a public man to be the subject of an outrage." [67] The rejection placed Van Buren even more firmly in the estimation of Jackson. With dignity and force, the president stated that those instructions of Van Buren as secretary of state to McLane which had led to Van Buren's rejection by the Senate, had been his instructions, and further justified Van Buren's position. He also stated that Van Buren had not had a hand in the differences between Calhoun and himself, and that there was no ground for imputing to Van Buren advice to make removals from office.[68] As Elijah Hayward

[62] Clay, *Private Correspondence*, IV, 259–260.
[63] Hamilton, *Reminiscences*, pp. 212–214, 215.
[64] *Cal. Van Buren Papers*, May 20 and June 23, 1831
[65] Van Buren, *Autobiography*, p. 446.
[66] Benton, *Thirty Years' View*, I, 215.
[67] *Ibid.*, I, 219; also Van Buren, *Autobiography*, p. 458.
[68] Shepard, *op. cit.*, p. 236.

wrote to Van Buren, the party was united by the Senate vote of rejection.[69] Jackson himself thought that the rejection would be beneficial to Van Buren.[70] Plans were made to put Van Buren forth as a candidate for the vice-presidency. He indicated his willingness to accept the nomination March 14, 1832, and was nominated in May by the convention at Baltimore on the first ballot.[71]

No platform was adopted at this convention, the issues being frankly left to the several states. The administration's opposition to internal improvements by the Federal government, already discussed, its stand against nullification and its opposition to the United States Bank, which will presently be discussed, and above all, Jackson himself, were the real questions at this election. Jackson and Van Buren were triumphantly elected.

On the question of nullification, Van Buren was non-committal. The leading opponents of the tariff in South Carolina were Crawford men [72] and hence Van Buren's former party associates. Though opposed to Calhoun at the start, the two parties in South Carolina became united when Calhoun shifted his ground on the tariff issue. In June, 1828, Jackson wrote to James Hamilton, Jr., that he abhorred the idea of a separate union, that the states were to check the Federal government and prevent consolidation. Bassett says that Jackson's words would have been understood by a man less devoted to his enthusiasm than Hamilton, to have been a warning. That part of the letter quoted by Bassett seems to me, however, to indicate unmistakably that, while Jackson might regret that the tariff issue had come up, he did not wish to take a definite stand on the question of state rights at this time.[73] When on April 15, 1830, it was decided to hold a Jefferson dinner, both Jackson and Van Buren were invited to attend. The invitations were accepted. Van Buren states that Jackson's toast, "*Our federal union — it must be*

[69] *Cal. Van Buren Papers*, Jan. 30, 1832; also J. Hoyt to Van Buren, February 7, 1832.

[70] *Ibid.*, Jackson to Van Buren, Feb. 9 (?), 1832.

[71] *Ibid.*, Van Buren to Marcy, March 14, 1832; Shepard, *op. cit.*, p. 239.

[72] Bassett, *op. cit.*, II, 548.

[73] *Ibid.*, II, 555.

preserved," was decided upon in conference between the president and his secretary of state.[74] Jackson's stand on nullification seems to have been his own policy. Van Buren did not entirely approve of the nullification proclamation,[75] while Jackson was prepared to use force if necessary.[76] Calhoun certainly was desirous of bringing Van Buren into the trouble.[77] Possibly the nullifiers hoped to influence Jackson through Van Buren.[78]

Van Buren "was opposed to the bank on constitutional grounds," says Bassett.[79] J. A. Hamilton, however, reported the following conversation with Van Buren: "Van Buren, you are against the bank on the ground of its unconstitutionality." He said, "Oh! no, I believe with Mr. Madison that the contemporaneous recognition of the constitutional power to establish a bank by all the departments of the government, and with the concurrence of the people, has settled the question in favor of the power." [80] In 1826 Van Buren had declared against the bank. In 1829 his message as governor of New York had contained a phrase which evidenced a dislike of all national monopolies.[81] He and other members of his party, however, in spite of this stand petitioned for an office of the bank at Albany.[82]

Jackson, according to Catterall, unquestionably showed signs of opposing the U. S. Bank before he arrived in Washington.[83] Jackson even believed that he had mentioned the bank in the first draft of the inaugural address. He was probably in error. The rumor had spread, however, as early as January, 1829, that the administration was hostile to the bank. The following December, in his first annual message, Jackson said of the bank: "It must be admitted by all that it has failed in the great end

[74] Van Buren, *Autobiography*, pp. 413–415.

[75] *Ibid.*, pp. 547–548.

[76] Bassett, *op. cit.*, II, 581; Jackson to Van Buren, January 13, 1833.

[77] Calhoun, *Correspondence*, pp. 289, 290.

[78] Bassett, *op. cit.*, II, 558–559.

[79] Bassett, *op. cit.*, II, 631.

[80] Hamilton, *Reminiscences*, p. 150.

[81] Catterall, *Second Bank of the U. S.*, p. 175 note; Van Buren, *Autobiography*, p. 221.

[82] Catterall, *Second Bank*, p. 399.

[83] *Ibid.*, pp. 182–184.

of establishing a uniform and sound currency." [84] An interview with Jackson, which Biddle reports, took place about the same time. Jackson said that he did not dislike Biddle's bank any more than all banks, but that since he had read the history of the South Sea bubble, he had been afraid of banks.[85]

On December 10, 1829, Alexander Hamilton, Jr., wrote to Biddle: "I would suggest the propriety of abstaining from the expression of any opinion intimating a want of fairness or integrity in the President. I am satisfied that he feels no personal hostility and consequently no conduct of the bank ought to create such a feeling. I would next observe, have no confidence in Van Buren; as an aspirant for the chief magistracy, he is without principle and totally destitute of sincerity." [86] The idea that Van Buren was responsible for bringing up the bank question was very persistent. G. F. Mercer wrote to Biddle in 1831: "Van Buren your enemy is in England. If a candidate four years hence for the presidency his influence will be felt to your prejudice." [87] In 1832, Charles Jared Ingersoll reported to Biddle that "Louis Williams of North Carolina says that all his [Jackson's] opposition to the Bank of the United States was fomented if not created by Van Buren who calculated that he could render his ascendancy in New York subservient to the prejudices of Virginia, and that Pennsylvania would acquiesce, which three States thus united would give him a broad basis for the future presidency." [88] It is interesting to note what Clay wrote in a letter to Biddle, June 14, 1830: "Unless I am deceived by information, received from one of the most intelligent citizens of Virginia, the plan was laid at Richmond during a visit made to that place by the Secretary of State last autumn, to make the destruction of the Bank the basis of the next Presidential Election. The message of the President, and other indications are the supposed consequences of that plan." [89] Van Buren visited Richmond about this time and his intimacy with

[84] Richardson, *Messages and Papers*, II, 462.

[85] McGrane (ed.), *Correspondence of Nicholas Biddle*, p. 93 and note; Catterall, *Second Bank*, p. 184 note; Bassett, *op. cit.*, II, 499–500.

[86] McGrane (ed.), *Correspondence of Nicholas Biddle*, p. 89.

[87] *Ibid.*, p. 141. [88] *Ibid.*, p. 172. [89] *Ibid.*, p. 105.

the Richmond politicians makes it more than possible that an interview took place. Another correspondent reported to Biddle on the other hand that Van Buren had told him that he "disapproved of that part of the message and was not hostile to the Bank." [90] Biddle himself held Van Buren in high esteem and often reiterated his belief that the latter was "neither the instigator nor the advisor of the President's remarks." [91] From all the evidence one is compelled to accept Catterall's conclusion that Amos Kendall was "the most powerful, most determined, and most subtle enemy of the bank." [92]

Certainly when it came to the removal of the bank deposits, Van Buren was placed in a difficult position. His support of McLane in general caused him to be considered friendly to the bank democrats. James Gordon Bennett thought that the removal of the deposits was planned by Amos Kendall to ruin Van Buren.[93] Roger Brooke Taney was evidently influential in the removal of the deposits.[94]

One more item in regard to Van Buren's influence. In cabinet session, the question of issuing letters of marque and reprisal against the French came up. Taney gives Van Buren credit for preventing so rash a step. "And I have always believed," he wrote, "that it was owing to your ready and earnest interposition that the President was induced to take a calm and more deliberate view of the whole subject and to abandon a measure which I then thought and still [1860] think would have resulted in the overthrow of his administration and the recharter and victory of the Bank and perhaps plunged us suddenly and unprepared as we were into hostilities with France." [95]

In conclusion, Jackson and Van Buren seem strangely complementary. Jackson was possessed of military fame but he was not equally skilled as a politician. Van Buren was by nature a pacifist, while in politics he won the name of the 'little magician.' Jackson was capable of strong decisive action in a crisis.

[90] *Ibid.*, p. 104.

[91] *Ibid.*, p. 102 note.

[92] Catterall, *Second Bank*, p. 193.

[93] Bassett, *op. cit.*, II, 640.

[94] "Letters of Jackson to Taney," *Maryland Historical Magazine*, IV (1909), 297–313.

[95] "Taney to Van Buren," *Maryland Historical Magazine*, X (1915), 22.

In contrast, Van Buren too much weighed the effect of all his actions. It was this latter characteristic that gave him the reputation of being 'dark,' 'mysterious,' and 'designing.' His negative course of conduct created such opinions. "He neither asserts nor contradicts," said C. A. Davis.

The friendship between the two men was due to Van Buren's ability to make himself useful and agreeable. Then too, in spite of the many favorable portraits of Van Buren, he was not an educated man.[96] "Van Buren cannot speak or write the English language correctly," wrote John Randolph.[97] "His knowledge of books outside his profession was more limited than that of any other public man I ever knew," said J. A. Hamilton.[98] It may well have been that Jackson was most at ease in the presence of Van Buren.[99]

It seems to me that the most that can be claimed for Van Buren's influence on Jackson is that his conciliatory attitude softened Jackson's harshness without depriving it of its strength and force. With his eye on the presidency during nearly the whole of Jackson's terms, he was too closely concerned with his own future to let himself be completely identified with any policy which might prove unpopular.

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[96] Bassett, *op. cit.*, I, xi.

[97] Bruce, *John Randolph of Roanoke*, II, 13–14, Randolph to Jackson, March 18, 1832.

[98] Hamilton, *Reminiscences*, p. 42.

[99] For other opinions of Van Buren, see Adams, *Memoirs*, VII, 129; McGrane (ed.), *Correspondence of Nicholas Biddle*, pp. 102–103.

THE PORTUGUESE TRIBUTE TO ROME, 1179–1213

BENJAMIN WEBB WHEELER

IN December, 1143, Affonso Henriques of Portugal addressed a letter to the pope.[1] He had chosen to have Saint Peter as his "patron and advocate" and had done homage to the Lord and to the pope through the hands of a papal legate. What was more to the point, he promised on behalf of himself and his successors, in perpetuity, to render to "St. Peter and the Holy Roman Church" an annual tribute of four ounces of gold. This promise he made upon the stipulated condition that he, his lands, and his successors should enjoy the "protection and comfort of the Apostolic See," and that he should never be obliged to acknowledge any suzerainty "ecclesiastical or secular, save that of the Apostolic See or its direct representatives."

Since the foundation of the county of Portugal in 1095, as a fief of the kingdom of Galicia, the Portuguese sovereigns had been struggling almost continuously to establish themselves in possession of an independent title. Within the year Affonso Henriques had succeeded in securing from King Alfonso VII of Castile, Leon and Galicia, a treaty whereby the latter agreed to recognize the Portuguese claim to the title of king. In return the newly recognized king of Portugal apparently agreed to recognize

[1] Published in Santa Rosa de Viterbo, *Elucidario* (2d ed., 1865), I: 267–268; Brandão, *Monarchia Lusytanea*, X: 10; Baluze, *Miscellanea* II: 220; *ibid.*, (ed. Mansi, 1761–1764), III: 78; summarized by Visconde de Santarem, *Quadro elementar das relações politicas e diplomaticas de Portugal*, IX: 8. The authenticity of this document and of Lucius II's answer was impugned by J. P. Ribeiro, *Dissertacões chronologicas e criticas*, I: 65 ff. His objections are adequately answered by Herculano, *Historia de Portugal* (6th ed., 1901), I: 525–536. The date given in Viterbo's copy appears to be the correct one. H. Schäfer, *Geschichte von Portugal*, I: 54, writing before Herculano, followed Ribeiro in questioning the authenticity of the documents.

Alfonso VII's claim to suzerainty over a part of his domains, at least, and probably he engaged himself to respect the pretentions of Alfonso VII to the title of "Emperor of the Spains." [2]

At all events no treaty was certain security and the remote sovereignty of Rome was preferable to the more immediate claims of a powerful Spanish king. The acceptance by the papacy of Affonso's tribute would greatly strengthen his claim to independence.

Affonso in his letter to the pope styles himself king. The answer of Pope Lucius II [3] is decidedly cautious. He accepts the homage done the legate and designates the archbishop of Braga to receive the annual tribute on behalf of the papacy. Although he promises Affonso and his successors, in general terms, the protection of the Apostolic See, he avoids any specific acceptance of those terms which might bring him into conflict with temporal claims of suzerainty. Furthermore Affonso is addressed as duke and not as king.

Nevertheless the Portuguese sovereign seems to have considered it advisable to meet his tribute payments for the next thirty-six years. The claims advanced in subsequent negotiations regarding unpaid tribute are reckoned from the year 1179.

In that year Affonso Henriques is addressed as king for the first time in a papal document.[4] After complimenting Affonso on his services to Christendom in extending her borders against the Moslems, Pope Alexander III confirms him in possession of his kingdom and in the rights and privileges pertaining to the royal title. All lands which he may, in the future, be able to take from the Mohammedans, and to which no Christian king has a prior claim, are also conferred upon him. In recognition of all this Affonso had declared himself tributary to the pope in the amount of two marks of gold yearly and was to enjoy the full protection of the spiritual arms over both his person and kingdom.

[2] The exact nature of the agreement between the two kings is not known. See Herculano, *op. cit.*, I: 338, and the critical analysis of the evidence in the note "Sujeição ao Papa," *ibid.*, pp. 525–536.

[3] Baluze, *loc. cit.*

[4] Bull of Alexander III, May 23, 1179, in Sousa, *Historia genealogica da casa real portuguesa*, I: 7–8.

Failure to continue the promised payment after 1179 led to a series of negotiations known to us chiefly from the papal letter and concluding in 1213 with a papal legate's receipt for a stated sum, to cover the payments for a stated number of years.[5]

In addition to the expressions already mentioned as designations for the amount of the original tribute established in 1143 and the increased tribute of 1179, there is found in the correspondence the term 'one hundred byzants.' This sum has been regarded as another equivalent for the total annual tribute promised in 1179, including the original four ounces of gold.[6]

It is the endeavor of this paper to show that it more probably represented not that total, but the difference between the total and the original tribute. In other words that two marks of gold equaled four ounces of gold plus one hundred byzants.

The former interpretation lays the pope open, at one point in the negotiations, to the charge of deliberately instructing his legate to collect a double payment, a misunderstanding which the interpretation herein suggested will obviate. Furthermore, a correct understanding of the relative value of these amounts, and of the Portuguese coins in which the final payment in 1213 was actually made, is of assistance in solving the apparent inconsistency between the amount paid in that year and payments previously made.

A reëxamination of the relative values of the amounts involved in these negotiations has, therefore, more than a perfunctory relationship to the whole problem of Innocent III's relations with the Portuguese monarchy.

On May, 7, 1190, Clement III sent Affonso Henriques' son and successor, Sancho I, a copy of the bull of 1179 with only the necessary minor changes required by the sense.[7] Aside from this we have no record of further negotiations until 1198, when Innocent III, always an aggressive guardian of ecclesiastical rights, came to the papal throne.

Innocent's letter of April 24, 1198, to King Sancho I sum-

[5] Summarized by Santarem, *Quadro Elementar*, IX: 60.
[6] Ribeiro, *op. cit.*, I: 76; Herculano, *op. cit.*, II: 90 and 483–484.
[7] Summarized in Santarem, *Quadro elementar*, IX: 25–26.

marizes the relations between Rome and Coimbra from 1143 and is our principal source of information for the nineteen years between 1179 and 1198.[8]

The term one hundred byzants appears in this letter for the first time in our chain of documents. Three sums are mentioned: the original tribute of four ounces of gold; one hundred byzants established as an annual tribute on recognition of the royal title; and a lump sum of one thousand byzants, which Affonso Henriques had delivered to the pope. As to whether the hundred byzants are intended to represent the total increased tribute, or only the amount of the increment, the document is not entirely clear. It only tells us that four ounces of gold were promised in the time of Lucius II and one hundred byzants in the time of Alexander III.[9] It does not specifically state that the hundred byzants were an amount additional to the four ounces of gold. Furthermore, Sancho had been approached by a legate of Celestine III and had evaded payment by interpreting his father's contribution of a thousand byzants as an exemption from *all* payments for *ten* years.[10] In view of this fact particularly, it may at first seem more reasonable to interpret the hundred byzants and

[8] *Inn. III Epist.*, I: 99; in Migne, *Patrol. Lat.*, CCXIV: 87–88.

[9] *Ibid.*, col. 87 C–87 D.

[10] *Ibid.*, col. 88 A. This interpretation is followed by Schäfer, *Geschichte von Portugal*, I: 55, and Herculano, *Historia de Portugal*, II: 89. Luchaire, *Innocent III et les royautés vassales*, interprets the words *licet illos eidem praedecessori nostro non pro censu sed . . . liberaliter donavisset* as part of the indirect discourse and therefore as part of the evasive answer of Sancho, who was anxious to clear himself of every tributary relationship to Rome. Luchaire's translation does not seem quite justifiable. *Illos* must refer back to the *mille aureos*, which it is claimed Sancho definitely put forward as a payment made *pro annuali censu decem annorum*. Sancho does not deny that the hundred byzants annually is an obligation, but claims that it has been paid in advance. The Portuguese king, or his chancellor, seems to have been primarily interested in effecting an economy by avoiding payment rather than in the abstract problem of evading the tributary relationship by claiming that previous payments had been free gifts. We shall see that in the course of the year 1198 the Portuguese were glad to recognize the tributary obligation to the amount of four ounces of gold if they could thereby hope to escape the larger payment.

As suggested by Luchaire (*op. cit.*, p. 19) and Herculano (*op. cit.*, p. 90) the chancellor, Julião was probably actually responsible for the diplomacy carried on in the king's name.

the two marks of gold as equivalents, but a more careful comparison of the documents makes this interpretation appear less plausible.

When Celestine III became pope (March 30, 1191), more than ten years had already elapsed since 1179. Sancho, therefore, could not seriously claim exemption from the resumption of payments. His answer to Celestine's legate was a play for time or a move to secure full credit for the thousand byzants before resuming payments and making adjustments. His advisers were apparently ready to try every trick to delay proceedings.

Two papal letters of December 9, 1198, one to the king [11] and one to the legate Rainer,[12] show quite clearly that a distinction had been drawn between the two accounts, that of four ounces of gold and that of one hundred byzants. Sancho had forwarded to Rome 504 *maravedís,* in payment of the annual tribute of four ounces of gold accrued since the (third) Lateran council (1179). Since this is not a round sum, it would lead us to assume that it represents some definite number of coins to the year and to the ounce. The only factors by which 504 is evenly divisible, and which come anywhere near the requirements of the case, are eighteen and twenty-eight. That is to say, 504 maravedís represents the payment for eighteen years at seven maravedís to the ounce.

Sancho had professed to be imperfectly informed regarding his father's promise of one hundred byzants and his contribution of one thousand and had referred the matter to the pope for a definite decision. If he had entertained hopes that Innocent would be unable to give documentary proof of his case, they were dispelled. The pope enclosed a rescript of the old king's letter of transmittal, making it clear that the thousand gold pieces had been a free gift.

The 504 maravedís are most courteously acknowledged and the pope protests his deep regard for the king and his kingdom, but concludes by admonishing him to complete his payments without delay. At the same time the letter addressed to the

[11] *Inn. III Epist.*, i, 448; Migne, *Patrol. Lat.*, CCXIV: 424–425.
[12] *Inn. III Epist.*, i, 449; Migne, *Patrol. Lat.*, CCXIV: 425.

legate makes similar acknowledgment of the 504 maravedís, but in concluding directs that the king be forced to pay without any deduction (*sine qualibet diminutione*). This leads Herculano [13] to the conclusion that Innocent was deliberately demanding a double payment by disregarding the payment for which he had just receipted. The correspondence, in fact, carefully distinguishes between the two accounts. The 504 maravedís are carefully receipted for as covering the obligation of four ounces of gold annually. Then the letter takes up the additional annual obligation of one hundred byzants and demands payment in full, that is, without deduction for Affonso Henriques' thousand byzants which had now been shown to have been a free contribution.

The expression 'two marks of gold' is employed in four documents, the bull of Alexander III of 1179, two modified copies of the same, one sent by Clement III in 1190 and one by Innocent III in 1212, and in the final receipt of 1213. In each case there can be no doubt that it is intended to signify the total annual payment after 1179.

The term 'four ounces of gold' appears in the letter of April 24, 1198, and the two of December 9 of the same year. In these three letters the distinction is made between the tribute promised in 1143 and that promised in 1179, which is referred to as one hundred byzants or gold pieces.[14]

Maravedís are mentioned in two documents, the letter of April 24, 1198, and the receipt which concludes the negotiations in 1213. In both cases they represent a definite payment made by the Portuguese crown and are equated with moneys of account; in the former document with the ounce at seven to the ounce and in the latter with the mark at sixty to the mark.

If we are to assume that one hundred byzants or *aurei* are

[13] *Op. cit.*, II: 90 and 483–484.

[14] It is referred to as 'one hundred byzants' in the April letter and as 'one hundred *aurei*' or gold pieces in the two of December 9. The free gift is referred to in the same documents as 'a thousand byzants' and 'one thousand *aurei*' respectively. The terms 'gold pieces' and 'byzants' are clearly identical and appear only in those documents where a distinction is made between the two accounts.

identical with two marks of gold, then they are also identical with 120 maravedís.[15] But byzants and maravedís are both known coins. Specimens of the former from this period weigh from 60 to 66 grains [16] and of the latter from 73 to 76.[17] To regard fifty of the smaller coins as the equivalent of sixty of the larger is obviously absurd.

Even if we regard the term byzant as loosely used for any gold coin, and make every allowance for the instability of weights and measures in the Middle Ages, the discrepancy is too great. The term byzant must at least have connoted a general standard of weight comparable to that of the actual Byzantine coins. Marks and ounces must have been at least reasonably stable as used in negotiations between the same two parties over a period of no more than three quarters of a century.

It is safe to say that two marks of gold and one hundred byzants are not equivalents and the use of the terms in the documents makes it seem probable that two marks of gold represent the sum of the original tribute of four ounces of gold and an additional amount of one hundred byzants promised in 1179. The irregularity of standards makes it impossible to arrive at an exact mathematical proof. The explanation may, however, be shown to be plausible. If we assume an average byzant of 65 grains and an average maravedí of 75, one hundred byzants and four ounces of gold, reckoning seven maravedís to the ounce, would give us a weight of eighty-six hundred grains as the equivalent of two marks, while seventy-five times one hundred and twenty (the mark having been reckoned at sixty maravedís in the receipt of 1213) amounts to nine thousand, a variation of less than five per cent.

In 1179 Affonso Henriques had added to his annual tribute of four ounces of gold an additional hundred byzants, raising his total annual obligation to two marks of gold. At the same time, or soon thereafter, he made a free gift of one thousand byzants,

[15] Ribeiro, *Dissertacões*, I: 76, concludes that such was the case.

[16] W. Wroth, *Imperial Byzantine Coins in the British Museum*, II: 588–590 and 599–600.

[17] A. C. Teixeira de Aragão, *Descripção geral de moedas*, I: 22–37 and 142–156.

but paid nothing further after that year. It is possible that the interrelations of the various amounts became confused even in the minds of those directly concerned. At least Clement III's formal communication [18] reminding Sancho of the tributary relationship, dispatched in May, 1190, might seem to imply that ten years had then elapsed and payments were again due and receivable. At least no other motive is apparent. Celestine III's legate was given an evasive answer, but Innocent made the matter so clear that the king could no longer be or pretend to be in doubt. It is evident that both pope and king in 1198 clearly understood the distinction between the various sums.

Sancho certainly got the worst of his argument with the pope. Did he pay? Herculano [19] and Luchaire [20] assume that he did. The chief reason for their conclusion is that he needed Innocent's support. On the other hand Innocent's diplomatic interests in Spain at the time would have made a break with Portugal unwise, in any case,[21] and the settlement made in 1213 with Sancho's son and successor, Affonso II, would seem to imply that payments were not resumed in 1198.

From 1208 to 1210 Sancho became involved in a bitter quarrel with the great prelates of his realm, which brought him for a time into open conflict with Innocent. In 1210, threatened by the death which overtook him in the following year, he repented and yielded to the church, naming Innocent a guarantor of his will. Domestic disorders soon arose between Affonso II and his sisters, making the moral support of the pope most desirable.[22] On April 16, 1212, another bull, almost identical with those dispatched by Alexander III in 1179 and by Clement III in 1190, was sent to the new king.[23] Eight days later another communication was addressed to the king admonishing him that

[18] As cited in note 7 above.

[19] *Op. cit.*, II: 90–91.

[20] *Op. cit.*, p. 10.

[21] Innocent was actively engaged in an effort to unite the Christian kings of Spain and force the hand of the kings of Navarre and Leon, who persisted in forming alliances with the Moslems. See Wheeler, "Papacy and Hispanic Interstate Relations," *Papers of the Michigan Academy of Science, Arts and Letters*, V (1925): 301–303, and documents there cited.

[22] See the accounts of Herculano, *op. cit.*, II: 115–190; Schäfer, *op. cit.*, I: 115–137; Luchaire, *op. cit.*, pp. 5–27.

[23] *Inn. III Epist.*, xv, 24; Migne, *Patrol. Lat.*, CCXVI: 562–563.

he must make his payments and not only the current ones, but the accumulated back payments as well.[24] Negotiations were apparently under way and possibly Affonso II had already resumed current payments.

The final settlement of the controversey is indicated by the papal legate's receipt of December, 1213. The payment made consisted of 3,360 Portuguese maravedís and covered twenty-eight years' payments at two marks per year.

Ribeiro rejected the document as a forgery.[25] He had various reasons, but the motivating one was the inconsistency in dates. The receipt was specifically issued to cover payments for twenty-eight years. Herculano accepts the document as authentic and successfully answers all of Ribeiro's arguments but one. Assuming on purely conjectural ground and from the silence of the documents that Sancho paid the full tribute from 1198 to the end of his reign, he decides that Affonso II settled the account for his father's reign and his own, but not for that period of his grandfather's reign for which payment had never been made. Having already assumed that Sancho resumed current payments in 1198, he concludes that Affonso overpaid the papacy by 1,680 maravedís, that is to say, for the fourteen years (1198–1211 inclusive) for which payments had already been made. The discrepancy as to dates and figures is dismissed with the statement that the curia was not over-nice in its accounting, and would not object to being overpaid. In support of this conclusion regarding the laxity of papal accounting Herculano cites the example of Innocent's letter to his legate Rainer, in which he instructs him to demand of Sancho full payment, although he has just acknowledged receipt of 504 maravedís.[26] As we have already seen, this is a misinterpretation of the document due to a failure to distinguish between the two accounts.

Herculano's interpretation is followed, in its essentials, by Luchaire.[27]

[24] Summarized in Santarem, *Quadro elementar*, IX: 55.

[25] *Dissert. Chronol.*, I: 72.

[26] See his note, "Pagamento do censo ao papa em 1213," *op. cit.*, II: 483–484; *ibid.*, p. 190.

[27] *Op. cit.*, pp. 26–27.

The papal documents with which we have dealt, especially those of Innocent III are, on the whole, monuments of accurate accounting. There is no reason to accuse him of dishonesty in money matters. It is not to be assumed that the papacy would disregard payments duly made, or that it would overlook five or six unpaid years (the last years of Affonso Henriques' reign), and certainly the Portuguese court would not have been likely to make an error so greatly to its own disadvantage.

It is not possible to solve the problem without introducing some element of conjecture, but it is not necessary to go so far afield in order to bring the receipt of 1213 into harmony with the established facts. We cannot assume that our record includes all payments made, but we may expect all payments to have been duly accredited on the final settlement.[28]

The only payment known to have been made after 1179 is that of 504 maravedís. If this amount were allowed to apply against the total sum of two marks a year, instead of the four ounces, as originally intended by Sancho, it would amount, at sixty maravedís to the mark, to a fraction over four years' payments. If this sum were allowed so to apply, we would have accounted for thirty-two years' payments, covering the years 1180–1211, inclusive. As we have already seen, the papal documents of the year 1212 may well imply that current payments were resumed in that year.

Our records are fragmentary, and with the exception of Affonso Henriques' letter of 1143 and the receipt of 1213, are limited to the letters of one of the negotiating parties. As in all diplomatic negotiations, much must have been accomplished by word of mouth which is not on record. It is impossible to reconstruct all the facts exactly, but the known facts indicate at least a possible solution which does not make it necessary to assume double payment or the disregard of several unpaid years.

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[28] It is to be hoped that Paul Kehr's *Papsturkunden in Spanien, Vorarbeiten zur Hispania Pontificia* will supply further material upon this subject. Volume I, *Katalinien* (Weidmannsche Buchhandlung, Berlin, 1926), is now published and it is understood that the volume dealing with Portugal will appear in 1927.

THE DATE OF THE BHAGVADGÎTÂ

CHANDRAKANT G. KULKARNI

INTRODUCTION

THE chronology of the ancient Indic literature is so meager [1] that the dates of the composition of even the greatest Sanskrit classics have been in controversy.[2] The authors themselves were reticent about their works and also the time when they were written, perhaps because of a canon in vogue in their time that it was vain and foolish for an author to mention his personal life in his work. In almost all the fields of Sanskrit literature there is no exact dating and often little knowledge of the surroundings of the writer or the composer, and of the influences under which he labored to produce his work. Hence, attempts to determine dates, even approximately, have given rise to various differences of opinion among those engaged in the field of Sanskrit literature.

The aim of the writer of this paper is to discuss briefly the approximate date of the Bhagvadgîtâ. In doing this, diverse sources of evidence from ancient Sanskrit and Pâli literature have been freely consulted. In a short paper of this nature it is impossible to discuss in detail the various theories of the date of the Bhagvadgîtâ, but a full list of the works consulted, with references, is given in the footnotes so that anyone wishing to pursue independently the study of this topic can do so with the least difficulty and form his own conclusions.

The reason for the special interest in the Bhagvadgîtâ [3] lies in the fact that there are in the Bhagvadgîtâ and the New Testa-

[1] F. Max Müller, *Hibbert Lectures*, p. 131.

[2] Cousin, *Lectures on the History of the Modern Philosophy* (translated by O. W. Wight), I: 49–50. Maurice's and Ritter's *Histories of Philosophy*.

[3] There are many editions of the Bhagvadgîtâ with authoritative commentaries, but the one I have used is published in Bombay by the Gu-

ment more than one hundred verses almost identical in idea and phraseology which students have found it exceedingly difficult to explain, except by a theory of influence of India on the West, or vice versa. Unfortunately prejudice has had much greater weight with some of the controversialists [4] than scholarship, since they have been eager to prove the priority of the New Testament. The question has been more discussed in Europe, perhaps, than in India, and has engaged the attention particularly of zealous proponents of the theory that Christian philosophy arose *de novo*, having no forerunner that influenced it other than Judaism. The point of view of Indian scholars has been held by such a distinguished man as Max Müller,[5] and by others.

It is clear that the controversy involves the question whether the Bhagvadgîtâ is or is not a late addition to the Mahâbhârata.[6] According to the point of view of those who see borrowings from Christianity in the Bhagvadgîtâ, the latter must have been composed some centuries later than the other parts of the Mahâbhârata.

LORINCER'S WORK ON THE BHAGVADGÎTÂ

Lorincer, in a German translation of the Bhagvadgîtâ,[7] after pointing out more than a hundred examples of the similarity [8] between the Bhagvadgîtâ, and the New Testament, concluded that these must have been taken from the New Testament by the composer of the Bhagvadgîtâ [9] and included

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jerathi Printing Press. This edition is more useful than all the rest because it contains almost all the famous Sanskrit commentaries, about fifteen in number.

[4] Franz Lorincer, in the Introduction of *Die Bhagvad-Gîtâ*, presents a very lively controversy.

[5] F. Max Müller, *History of the Ancient Sanskrit Literature.*

[6] There are many editions of this national epic of India. The most famous ones are those published at Bombay, Madras and Calcutta, which are known as the Bombay, Madras and Calcutta editions. All the references in this paper are to the Calcutta edition, edited by Babu Pratap Chandra Ray, at Calcutta, India.

[7] Franz Lorincer, *Die Bhagvad-Gîtâ*, Breslau, 1869. Verlag von G. P. Aderholz Buchhandlung (G. Prosch.).

[8] *Op. cit.*, Anhang, pp. 273–285.

[9] *Op. cit.* See the Introduction and the Appendix.

in the Bhagvadgîtâ, which would consequently prove that the Bhagvadgîtâ originated after the New Testament was well established. Some of the illustrations that Lorincer used to prove his point are as follows:

Bhagvadgîtâ	New Testament	Bhagvadgîtâ	New Testament
3:6	Matt. 5. 28	7:1–2	I Cor. 2. 2
3:32	Titus 3. 10–11	7:14	Matt. 11. 28
3:34	Rom. 8. 7	7:15	John 8. 44
4:4	John 8. 57	7:16	Matt. 11. 5
4:5	John 8. 14	7:22	Jas. 1. 17
4:8	I John 3. 8	7:26	Heb. 4. 13
4:40	Mark 16. 16	7:27	Titus 3. 3
5:8–10	Col. 3. 17	7:28	Col. 1. 23
5:15	Eph. 4. 18	7:29	John 8. 51
5:16	II Cor. 4. 6	8:7	John 6. 37
5:23	Jas. 1. 12	8:9	I John 1. 5
6:10	Matt. 6. 6	8:22	Acts 17. 28
6:16	Matt. 11. 19	9:1	Luke 8. 10
6:39	John 6. 69		

Giving these citations and some other dubious evidence considered later, Lorincer concluded that the Bhagvadgîtâ was composed about 500 A.D.[10] The views of Lorincer were controverted very ably by K. T. Telang,[11] but have continued current in certain circles. It appears from Telang and Lok. B. G. Tilak [12] that Lorincer was not a very able Sanskritist and also that his Christianity had biased his conclusions.

GARBE'S *DIE BHAGVADGÎTÂ*

Garbe [13] in a German edition of the Bhagvadgîtâ states that the Bhagvadgîtâ was composed about 200 B.C. and was improved upon about 200 A.D. Although Garbe's work on the Bhagvadgîtâ

[10] *Op. cit.*, Introduction.

[11] Telang, K. T., *Bhagvadgîtâ Translated into English Blank Verse with Notes, etc.* Bombay, 1875.

[12] Tilak, Lok. B. G., *Gîtârahasaya.* Kesari Office, Poona, India, 1915, p. 580. This work is in Marathi, but Gîtârahasaya is so famous that it has been translated into many vernaculars in India. So far as the author of this paper is aware, it is not translated into English.

[13] Richard Garbe, *Die Bhagvadgîtâ aus dem Sanskrit Ubersetzt.* Leipzig, H. Haessel Verlag, 1905. See Introduction.

is excellent, still his conclusions on the date seem open to doubt. In support of his arguments he takes the meaning of *Yogonashasta* [14] ('Yoga destroyed') and attributes to this Yoga the meaning *Patañjala yoga,* which does not seem to be the correct interpretation; Yoga in this verse has the meaning *Karma yoga* and not *Patañjala yoga,* as Garbe interprets it.

OTHER WORKS ON THE BHAGVADGÎTÂ

There are other writers who are indifferent to the consideration of the authorship, date, etc., of the Bhagvadgîtâ. They dispose of the issue by saying, "We need not go into the question of whether we ought to regard Gîtâ as originally by one author or as belonging to one time." [15]

Again there are various books and papers published by missionary societies which dogmatically state that the Bhagvadgîtâ originated after the Christian Era. They need not be cited because they are nothing more than popular literature. They perpetuate sectarian views and are not important because of any contribution they make to the solution of problems, but solely because they largely influence popular belief.

LOK. TILAK'S WORK ON THE BHAGVADGÎTÂ

Lok. B. G. Tilak has settled beyond dispute that the Bhagvadgîtâ was the main text of the Bhâgvata Dharma ('Bhâgvata religion') which originated about 1400 B.C.[16] He thinks that the Bhagvadgîtâ was composed some years after this. The original Bhâgvata religion was Niskâmakarmâpradhâna, but it was later converted into Bhaktîpradhana and finally into Vishistâdwita. No more information than this is available on the original Bhâgvata religion and the original Bhagvadgîtâ. In the case of the present Mahâbhârata and the present Bhagvadgîtâ no more definite information was at hand until sixty or seventy years ago. Through the researches of the late R. G. Bhandarkar,[17]

[14] *Bhagvadgîtâ,* 4: 2.

[15] Dorothea Jane Stephen, *Studies in Early Indian Thought,* p. 118. Cambridge, 1918.

[16] *Gîtârahasaya,* pp. 534–553.

[17] "Consideration of the Date of the Mahâbhârata," *Journal of the Royal Asiatic Society of Bombay,* 1872.

K. T. Telang,[18] S. B. Dixit,[19] C. V. Vaidya,[20] F. Max Müller,[21] and numerous others, many facts have been uncovered which give sufficient evidence and testimony for the determination of the approximate time of the present Mahâbhârata and the Bhagvadgîtâ. Quite recently Trimbak Gurnath Kale[22] has presented two or three pieces of evidence that help to clear the date of the Bhagvadgîtâ more definitely. It was proved[23] by the late Lok. B. G. Tilak that the Bhagvadgîtâ is a part of the Mahâbhârata, that Bhagvadgîtâ and the Mahâbhârata are the works of the same author and hence must have been written at the same time. Since his work is not translated into English the arguments that Lok. Tilak adduces in support of his assertion are briefly summarized here:

1. There is distinct mention of the Bhagvadgîtâ as a part of the Mahâbhârata in many places in the Mahâbhârata itself. A few of the most important references to this effect are cited below.[24]

2. The style and the language of both the Mahâbhârata and the Bhagvadgîtâ belong to a period considerably prior to the epoch of the dramas and the poems, as may be seen from the perusal of both works. The style of both is simple, plain, direct and archaic.[25] Not very many compounds are to be found in either of the works under consideration. There is a marked contrast between the simple and beautiful style of the Mahâbhârata and the Bhagvadgîtâ and the more elaborate classical style of Bâna,[26] Dandin[27] and Bhavabhuti,[28] where long and tedious com-

[18] *Bhagvadgîtâ Translated into English Blank Verse with Notes, etc.* Bombay, 1875. *Bhagvadgîtâ Sanatsugâtîya and Anugîtâ*, Vol. VIII of *Sacred Books of the East*, edited by F. Max Müller.

[19] *Bhâratiya Jotisha Shâstra* ("Indian Science of Astronomy"). This book is in Marathi and, so far as I know, has not been translated into English.

[20] *The Mahâbhârata: A Criticism.* Bombay.

[21] *History of the Ancient Sanskrit Literature.*

[22] *The Vedic Magazine and Gurukula Samachar*, VII (Nos. 6–7): 528–532.

[23] *Gitârahasaya*, pp. 508–512.

[24] Mahâbhârata, Adi Parvana, 2: 69; 2: 247; 1: 179; Mahâbhârata, Shanti Parvana, 334–351; 346: 10; 348: 8; 348: 53.

[25] *The Bhagvadgîtâ*, 11: 15–50.

[26] Kâdambarî and Harshacharita.

[27] Dashakumaracharita.

[28] Uttarârâmacharita.

pounds are quite common. A comparison of the exquisite style of Kâlidâsa's works (Sakuntalâ, Raghûvamsa, Kumârasambhava, Meghaduta and others) with that of the Mahâbhârata and the Bhagvadgîtâ reveals that Kâlidâsa, whose works are not so replete with compounds that create a jingling sound, have still more compound words than the Mahâbhârata and the Bhagvadgîtâ.

3. In neither of the works under consideration is any attempt made at syntactical construction, such as is found in the works of the classical authors who flourished later.

4. Repetition of archaic words and phrases is found in both at several places. There are many Vedic words which do not occur in the classical literature, the production of a later period.

5. In neither work are rigid rules of versification followed like those in the works of the later period. The versification resembles that of the Vedic Samhitâs. Many places are found in both works where meter is not considered at all, although a greater number of the verses of the Bhagvadgîtâ conform to the metrical schemes laid down by the writers of prosody.

It is very interesting to note that K. T. Telang agrees on this point with Lok. Tilak, whose work we are discussing. This is what he has to say on the point under consideration: "From all the passages in the Bhagvadgîtâ which refer to the Vedas, I am inclined to draw the inference, that the Upanishads of the Vedas were composed at a time not far removed from the time of the composition of the Bhagvadgîtâ, and at that period the Upanishads had not risen to the position of the high importance which they afterwards commanded." [29]

6. Many verses are found in both works where there is exact identity of the thought and phraseology and, in some cases, even of the words. A few of the most important ones are given below.[30] There could be adduced more than a hundred similarities

[29] *Sacred Books of the East*, Vol. VIII, Introduction, p. 17.

[30]

The Mahâbhârata	The Bhagvadgîtâ
Bhisma Parvana, 51: 4	1: 9
Bhisma Parvana, 51: 6	1: 10
Bhisma Parvana, 51: 22–29	1: 12–19
Drona Parvana, 197: 50	1: 45
Santi Parvana, 224: 14	2: 19

of this nature. Lok. Tilak [31] calls attention in his work to more than fifty.

K. T. Telang subscribes with some reservation to the view of Lok. Tilak that the Bhagvadgîtâ is part of the Mahâbhârata. This is what he has to say about the question: "But yet, upon the whole, having regard to the fact that those ideas of unity on which Mr. Wheeler [32] and others set so much store are scarcely appropriate to our old literature; to the fact that Gîtâ fits pretty well into the setting given to it in the Bhisma Parvana; to the fact that the feeling of Arguna, which gives occasion to it, is not at all inconsistent, but is most consonant. . . . Having regard, I say, to all these facts, I am prepared to adhere, I will not say without diffidence, to the theory of the genuineness of the Bhagvadgîtâ as a portion of the Mahâbhârata." [33]

In order to facilitate the discussion of the subject, before entering into a detailed discussion on the various lines of evidence that have a direct bearing on the date of the Bhagvadgîtâ, I thought it desirable to consider the evidence for the date of the Mahâbhârata of which the Bhagvadgîtâ is a part, which would indirectly prove the date of the Gîtâ. The independent lines of evidence for the date of the Bhagvadgîtâ are considered later.

EVIDENCE FOR THE DATE OF THE MAHÂBHÂRATA

From History

Sardesai [34] during his travels in Jâva accumulated some information which throws considerable light on the date of the Mahâbhârata. He found there a copy of the Mahâbhârata

Bhisma Parvana, 124: 36	2: 31
Karna Parvana, 57: 2	2: 32
Udogaya Parvana, 45: 26	2: 46
Santi Parvana, 204: 16	2: 59
Vana Parvana, 210: 26	2: 67
Santi Parvana, 250: 9	2: 70

[31] *Gîtârahasaya*, pp. 512–514.

[32] Talboys Wheeler, *History of India*.

[33] *Sacred Books of the East*, Vol. VIII, p. 6.

[34] Sardesai's article appears in *Modern Review* (Calcutta, India), July, 1914, pp. 32–38.

containing eighteen Parvanas, which was taken to Jâva and Bâli about 400 A.D. In these islands they were translated into the ancient Kawi language, although at various places the Sanskrit verses are kept intact. Even today about eight Parvanas (Âdi, Virâta, Udogaya, Bhisma, Âsaramavâsi, Musala, Prâstânik, Swargârohana) may be found there in manuscripts and in the printed form. Lok. Tilak [35] has compared some Sanskrit verses from Udogaya Parvana in the Kawi version to those of the verses in the Udogaya Parvana original Mahâbhârata and finds some of them identical. This investigator proves that the Mahâbhârata must have originated in India before 400 B.C. But it cannot have gone so early to Jâva and Bâli. It must have been taken there after it had been widely diffused and had reached a very prominent position in India; otherwise it would hardly have gone there at all. There is also a translation of the Mahâbhârata into Tibetan,[36] but this is of a later date than the one in Kawi.

Recently a stone inscription [37] of a Gupta king who ruled India in Saka 367 (about 439 A.D.) has been discovered. It is definitely stated on it that the Mahâbhârata at that time contained 100,000 verses.

C. V. Vaidaya has shown definitely that Megasthenes, a Greek ambassador living at the court of King Chandragupta who ruled at Pâtaliputra (modern Pâtna) in 320 B.C., knew the Mahâbhârata. Unfortunately the entire book of Megasthenes is lost to us, but the extracts from his work by the different authors were collected and first published in German,[38] and later translated into English, by J. W. McCrindle.[39] The Herakles [40] described in this book, who was worshipped by the Sourasenoi tribe inhabiting Methor (modern Mathura), was Shri Krishna. It is also stated in the same book that this Herakles was of the fifteenth generation from Dionysus, the founder of the line. In

[35] *Gîtârahasaya*, pp. 554.
[36] Rockhill, *Life of Budda*, p. 228, note 1.
[37] *Inscriptiones Indicae*, Vol. III, p. 134.
[38] Schwanbeck, *Megasthenis Indica.* Bonn, Germany.
[39] *Ancient India as Described by Megasthenes and Arrian.* Tubner & Co., London, 1877.
[40] *Op. cit.*, pp. 200–205.

the Mahâbhârata it is mentioned [41] that Sri Krishna was fifteenth in descent from Dakshaprajâpati. Also the descriptions given by Megasthenes of the gold-digging ants,[42] men with ears large enough to sleep in, men without any mouths, without noses, with only one eye, with spider legs, etc.,[43] are identical with the descriptions in the Mahâbhârata.[44]

From the Sûtras

The Bhârata and the Mahâbhârata are clearly referred to in the Âsvalâyana Grihya-sûtras [45] in different places. Also a verse in Yayati discourse from the Mahâbhârata [46] is identical with one in Baudhâyana Grihya-sûtra.[47] Bühler claims that similarity of one verse does not support the contention that the Mahâbhârata was prior to Baudhâyana, which view would have been held valid had not Trimbak Gurnath Kale [48] offered some evidence on this point. Kale shows that the Visnûsahasaranâma is mentioned in Baudhâyana's Grihyâsheshasûtra.[49] To strengthen further the belief in our theory, there can be found in the same Sûtras [50] a verse identical with a verse in the Bhagvadgîtâ.[51] Bühler himself has determined by other evidence that Baudhâyana must have flourished between 500 and 400 B.C. This is his view towards the question under consideration: "Whether we assume with Professor Max Müller that the Sûtra period was one and the same for all the four Vedas, and fix its limits with him between 600–200 B.C., or whether we believe, as I am inclined to do, that the date of the Sûtra period differed from each Veda, still the incontestable conclusion is that the origin of Âpastambîya school cannot be placed in the early times of the

[41] The Mahâbhârata, Anu Parvana, 147: 25–33.
[42] *Ancient India as Described by Megasthenes and Arrian,* p. 94.
[43] *Op. cit.*, p. 74.
[44] Mahâbhârata, Sabhâ Parvana, 51 and 52.
[45] Âsavalâyana Grihya-sûtra, 3. 4. 4.
[46] Mahâbhârata, Adi Parvana, 78: 10.
[47] Baudhâyana Grihya-sûtra, 2. 2. 26.
[48] *The Vedic Magazine and Gurukula Samâchâr,* VII (Nos. 6–7): 528–32.
[49] Baudhâyana Grihyâsheshasûtra, 1. 22. 8.
[50] *Op. cit.,* 2. 22. 9.
[51] *The Bhagvadgîtâ,* 9: 26.

Vedic period, and probably falls in the last five centuries before the beginning of the Christian era." [52] Bühler further tells us that Âpastamba is younger than Baudhâyana and he gives the reason for his belief.[53]

From the Purânas

In the Mahâbhârata the incarnation of Vishnu is described, but no mention at all is made of Buddha who was considered an incarnation later. In Nârâyana Upâkhâyana [54] there is record of ten incarnations, the first being Hamsa and the last Kalki; there is no mention of Buddha. This indicates that the Mahâbhârata must have originated before Buddha was considered an incarnation. Edward E. Salisbury voices this opinion on the question under consideration: "But there can be no doubt that Buddhism is the development of the Indian mind subsequent to the form of religion which we find in the Epics." [55] The same author further writes: "The Ceylonese, Birmans, and Assamese fix the date of Buddha's death, which is the commencing point of their chronological reckoning, at 543 B.C. This may be shown to be probably correct. . . ." [56] This leads us to conclude that the Mahâbhârata probably existed before the period from 500 to 400 B.C. No doubt in the Mahâbhârata the words *buddha* and *pratîbuddha* are used,[57] but at these places they simply have the meaning, 'an individual who knows,' or 'an individual with steady mind,' and have nothing to do with Buddha and Buddhism.

From Dramatic Literature

A series of thirteen dramas recently issued in the Trivandrum Sanskrit Series have been attributed to Bhâsa by the editor, T. Ganapati Sastri. He concludes that the date of Bhâsa is

[52] *Sacred Books of the East,* Vol. II, Introduction, p. xviii.

[53] *Ibid.*

[54] Mahâbhârata, Shanti Parvana, 339: 100.

[55] "Memoir on the History of Buddhism," *Journal of the American Oriental Society,* 1: 90.

[56] *Ibid.*

[57] Santi Parvana, 194: 58, 307: 47, 343: 52.

between 300 and 200 B.C.[58] Another investigator concludes that it must be between 475 and 417 B.C.[59] It may be that the date of Bhâsa falls between these limits. This poet has taken the plots for many of his dramas from the Mahâbhârata. In Bâlakarita, one of his dramas, he speaks of Gopis and Shri Krisna's childhood, which indicates that Harîvamsa may have been known at that time.

From Buddhistic Literature

A Buddhist poet, Asvaghosha by name, flourished at the commencement of Shâlivan Shaka (about 78 A.D.),[60] as can be ascertained from the Buddhistic writings. This noted poet wrote two works, Saundarânanda and Buddha-karita,[61] which are now printed and published. In both these the Mahâbhârata is mentioned, which indicates that the Mahâbhârata must have existed at his time as a recognized authoritative text. Vagra-suchi Upanishad, another work by the same author,[62] contains many verses identical with those in the Mahâbhârata.[63]

From Astronomy

Shankar Balkrishna Dixit has published a book in Marathi[64] in which he has given evidence of an astronomical nature which tends to prove that the Mahâbhârata must have existed about 400 B.C. As his dissertation is very lengthy, it cannot even be summarized here.

There is no mention of the signs of the zodiac in the Mahâbhârata. The lunar chronology that is used in the Mahâbhârata is quite different. The signs of the zodiac were introduced into India with the conquest of Alexander the Great. This creates

[58] *Introduction to Svapanavâsavadattâ* (one of the dramas of Bhasa), by T. Ganapati Sastri. Trivandrum, 1914.

[59] *Svapanavâsavadattâ, with Introduction and Notes*, by Prof. H. B. Bhide.

[60] *Sacred Books of the East*, Vol. XIX, Introduction, p. xxxi.

[61] *Buddha-karita, with Introduction and Notes*, by N. S. Lokur.

[62] Published by Professor Weber in Germany, 1860.

[63] Harivamsa, 24: 20, 21; Santi Parvana 261: 17.

[64] See note 19.

a probability that the Mahâbhârata existed in India even before the conquest of Alexander the Great (about 325 B.C.).

The 1914 report of the Archaeological Department of Bombay Government deciphers some stone inscriptions which throw a little light on the point under discussion.

It will be clearly seen that the evidence cited above is from different sources and all tends to confirm the belief that the Mahâbhârata must have existed at least before 400 B.C., and as the Bhagvadgîtâ is a part of the Mahâbhârata and of the same authorship, it may be said that the time of the present Bhagvadgîtâ must also be about 400 B.C. Some investigators intimate that the Mahâbhârata and the Bhagvadgîtâ are by different authors and were written at different times and raise certain points of debatable nature in support of their theory, but K. T. Telang and Lok. B. G. Tilak have answered them with arguments so very convincing that I do not intend to discuss them here. It may be that certain verses have been taken from the Mahâbhârata, and certain others inserted, in its transmission from one generation to another during the course of 2,500 years, but the main point at issue is not about individual verses but the whole work. I feel towards this question, just as the late Lok. Tilak and Telang felt, that the Bhagvadgîtâ is a part of the original Mahâbhârata, and that it was not inserted into the Mahâbhârata afterwards.

EVIDENCE FOR THE DATE OF THE BHAGVADGÎTÂ

Since the Mahâbhârata originated about 400 B.C., and since the Bhagvadgîtâ is a part of it, we can conclude that the time of the origin of the Bhagvadgîtâ is identical with that of the Mahâbhârata. There is other evidence, however, to prove the date of the Bhagvadgîtâ independently of the Mahâbhârata, and this will be discussed briefly now.

K. T. Telang has ascertained from various sources that the Bhagvadgîtâ originated before Âpastamba, who flourished about 300 B.C.[65] R. G. Bhandarkar, whose researches in the field of the Sanskrit literature are practically unparalleled, also

[65] *Sacred Books of the East*, Vol. VIII, Introduction, pp. 21, 34.

agrees with the conclusion of Mr. Telang who puts the date of the Bhagvadgîtâ [66] at 300 B.C.

From the Bhâishas

Of all the commentaries and the bhâishas on the Bhagvadgîtâ that are handed down to us from generation to generation, the one by Sankarâkâraya is the oldest. Sankarâkâraya has also commented upon the Sanatsugâtîya chapter in the Mahâbhârata. In both these commentaries he has some citations from the Mahâbhârata, which shows that both the Mahâbhârata and the Bhagvadgîtâ were held in authority at his time. At the commencement of his bhâsaya on the Bhagvadgîtâ, Sankarâkâraya tells us that there existed many bhâishas on the Bhagvadgîtâ before him and states that he wrote a new bhâisha on it in support of his views on the interpretations of the Bhagvadgîtâ, and also to prove that the authors of the other bhâishas were in error in their interpretations. The date of Sankarâkâraya is settled as about 700 A.D. It is quite certain that the Bhagvadgîtâ existed many centuries before the date of Sankarâkâraya as a recognized portion of the Mahâbhârata. This we deduce from the fact that Sankarâkâraya himself tells us that there existed many commentaries on the Bhagvadgîtâ before his time. How many centuries we cannot definitely say.

From the Sûtras

Trimbak Gurnath Kale [67] has published some proofs which indicate that not only the Bhagvadgîtâ had been quoted by the Purânas and the classical authors, but also the Sûtras whose date is prior to those of the Purânas. Before the publication of his article the occidental Sanskrit scholars argued that the Bhagvadgîtâ is mentioned only in the classical Sanskrit poetry and the Purânas and not in any other works of ancient date. Hence they concluded that at the earliest the Bhagvadgîtâ must have originated about 200 B.C. But Kale's paper proves this view to be erroneous. He showed that some verses of Baudhâ-

[66] *Vaishnavism, Shaivism and Other Sects*, p. 13.
[67] See note 22.

yana's Grihyashesha Sûtras, and also some verses of Pitramedha Sûtra are identical in every respect with those in the Bhagvadgîtâ.[68] It is proved that Baudhâyana flourished 150 years before Âpastamba and the date of Âpastamba is settled by Bühler as about 300 B.C.[69] This certainly takes the Bhagvadgîtâ beyond 450 B.C. It may be argued that the verses under consideration were inserted afterwards in the texts. There is a very great improbability of insertion because of the fact that the Bhagvadgîtâ is from the beginning to the end recited even today and it was thought a sin to commit it to paper. Hence it could be clearly seen that it did not allow of any interpolations.

From Purânas

Different Gîtâs are composed in the fashion of the Bhagvadgîtâ and are included in Padma Purâna, Vishnu Purâna, and the like. For the Bhagvadgîtâ to have been taken as a model and imitated, it must have been held as a great sacred book of authority; otherwise there was no reason at all for imitation. The date of the various Purânas in which the several imitations of the Bhagvadgîtâ appear is about 200 A.D. This again indicates that the Bhagvadgîtâ must have originated some centuries before this.

From Dramatic Literature

K. T. Telang [70] has shown by conclusive evidence that Bâna, who flourished in the middle of the seventh century and had acquired great fame and reputation,[71] knew both the Bhagvadgîtâ and the Mahâbhârata. In Kâdambarî, one of the excellent works of Bâna, there are clear allusions to both the Bhagvadgîtâ and the Mahâbhârata in more than one place. The Mahâbhârata not only existed at the time of Bâna, but was publicly read and

[68] Compare the Bhagvadgîtâ, 9: 26; and Baudhâyana Grihyâshesha Sûtra, 2. 22. 9; the Bhagvadgîtâ, 2: 26; and Baudhâyana Pitramedha Sûtra (Question 3).

[69] See note 52.

[70] *Sacred Books of the East*, Vol. VIII, p. 28.

[71] *Indian Antiquary*, V: 70.

recited in his time.[72] This again shows that the Bhagvadgîtâ must have existed long before the date of Bâna.

Citations and references to the Bhagvadgîtâ may also be found in the works of Kâlidâsa, the foremost of the Sanskrit poets. There are some allusions to the Gîtâ in Kâlidâsa's works. Raghuvamsa,[73] 10: 31, is practically identical with Bhagvadgîtâ, 3: 32; Kumârasambhava,[74] 6: 67, with Bhagvadgîtâ, 10: 25. The date of Kâlidâsa is settled as about 500 A.D. This again shows that, in order to be current, the Bhagvadgîtâ must have existed many centuries before 500 A.D.

Recently the dramatic works of Bhâsa, a Sanskrit poet prior to Kâlidâsa, have been published. The twelfth verse of Karnabhâra is identical with Bhagvadgîtâ, 2: 37. It has been stated that Bhâsa knew Mahâbhârata. It does not seem improbable that Bhâsa had this verse of the Bhagvadgîtâ before his mind's eye when he wrote the twelfth verse of Karnabhâra. The date of Bhâsa is between 200 and 400 B.C.

The text of the Mahâbhârata that was taken to Jâva contains Bhisma Parvana and in this Bhisma Parvana is included the Gîtâ. The most remarkable fact is that many verses, about two hundred, from the different discourses of the Bhagvadgîtâ are found to be identical with the verses in the Bhagvadgîtâ of today. It is known that the Mahâbhârata was taken to Jâva about 400 A.D. Of course it must have originated many centuries before this in India.

All the evidence cited above tends to indicate that the Mahâbhârata, together with the Bhagvadgîtâ, must have originated in India between 500 and 300 B.C. Both Baudhâyana and Âsvalâyana knew it and knowledge of it among the various authors can be traced from Baudhâyana to the more recent Sankarâkâraya.

The evidence considered thus far is all from the Vedic literature. Now let us turn our attention towards the Buddhistic literature, which furnished us with the most important evidence

[72] *Journal of the Royal Asiatic Society*, Bombay, Vol. X, p. 87.
[73] A poetical work of Kâlidâsa.
[74] Another poetical work by Kâlidâsa.

for our theory that the Bhagvadgîtâ must have originated between 500 and 300 B.C.

From Buddhistic Literature

The Bhâgvata religion had originated before Buddhism, probably about 1400 B.C. But this does not necessarily mean that the Bhagvadgîtâ, the main text of the Bhâgvata religion, originated simultaneously with the Bhâgvata religion. Under these circumstances it is desirable to see whether the old Buddhistic writings mention the Bhagvadgîtâ in some of their works or not. The Buddhistic writings clearly state that the four Vedas, Vedangas, Vyakarna ('Grammar'), Jotisha ('Astronomy'), Nighantu, etc., existed at their time. This shows their priority. They also mention some other important works of Vedic origin, and state that these were already established at the time of Buddha. Hence it might be concluded that the Vedic religion had attained its full grandeur and development before the advent of Buddhism. Buddhism, although Anâtamavâdi in its essential points, resembles greatly the Sanâyasa path laid down in the Upanishads. At the time of Asoka, a Buddhist king who ruled in central India about 258 B.C., Buddhism underwent some vital changes. The Buddhist monks, instead of staying in the forests as preached in original Buddhism, went into the world to work for the public welfare. A superficial perusal of the history of Buddhism in India shows that it was at this time that the Buddhist monks went from India as far as China in the East, and Alexandria and Greece in the West. For a student interested in the rise and development of Buddhism, one of the most important questions is why the Buddhist monks took it upon themselves to go out into the world to work for the public welfare instead of staying in the forest. The religious Buddhistic literature definitely states that a monk who has reached Aharatâvastâ should do nothing but wander in the forest like a rhinoceros. The same view is again expressed in the stories of Saunakavalis, one of the disciples of Buddha, in which he says *Katasa patichaya nathi Karanayam no vijjati*, 'He should not care for anything nor do anything.' This is the same as the Sanayâsa path

described in the Upanishads; *Karanayam na vijjati* ('has nothing left to be done') is exactly similar to *Tasaya Karayam no Vidayati* from the Bhagvadgîtâ. Even the words are the same, the only difference being that the former is in Pâli and the latter in Sanskrit. When the Buddhist monks, instead of wandering in the forest as enjoined, started to enter the world for the welfare of humanity, there arose a clash in Buddhism. They divided into two sects, one (Hinayâna) believing, as enjoined by Buddha and his immediate disciples, that as soon as a monk reached Aharatâvastâ he should do nothing but wander in the forest, the other (Mahâyâna) disagreed with the original teachings and went out into the world.

Asvaghosha, a Buddhist poet belonging to the Mahâyâna sect, was of the opinion that the Buddhist monks should go into the world and work for the public welfare instead of wandering in the forest after reaching the Aharatâvastâ. This view of his is gathered from Saundarânanda, 18: 54–57. These verses are identical in meaning and spirit with 3: 17–19 of the Bhagvadgîtâ and were probably taken from the Bhagvadgîtâ. Asvaghosha lived after the time of the Bhagvadgîtâ and the Mahâbhârata. This is not at all a matter of opinion or conjecture. It is clearly stated in Târânath, a text in Tibetan, on the history of Buddhism written by the Buddhists, that the change from the original monastic Buddhism to Karmayoga was suggested to Râhulabhadra, the preceptor of Nâgârjuna, the proponent of the Mahâyâna sect, through the philosophy of Sri Krishna and Ganesha.[75] This text was first translated from Tibetan to Russian and then to German. There is no translation of it in English. This statement is taken from an extract from Kern's work. Kern also believes that by the philosophy of Shri Krishna is meant the Bhagvadgîtâ. It is admitted in their writings by the Buddhist authors that the changes from the original monastic Buddhism to devotional Karmayoga were brought about through the influence of the Bhagvadgîtâ (Asvaghosha and others). The date of Nâgârjuna is about 150 B.C. This definitely shows that the Bhagvadgîtâ must have existed before the Mahâyâna sect

[75] *Histoire du Bouddhisme dans l'Inde,* Tome 2, pp. 434–435.

originated. Leaving time for the taking these views from the Gîtâ and assimilating them, we can safely say that the Bhagvadgîtâ was composed about 400 to 300 B.C.

SUMMARY

1. The Bhagvadgîtâ is a part of the Mahâbhârata and is the work of the same author and belongs to the same time as the Mahâbhârata.

2. The date of the Mahâbhârata and Bhagvadgîtâ is between 500 and 300 B.C., so far as we can determine from the perusal of the existing literature.

3. It may be that the original Mahâbhârata and the original Bhagvadgîtâ are older by many centuries than the date ascertained above, but extant evidence does not allow us to claim it.

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THE HAMITIC BACKGROUND OF SEMITISM

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IT IS now generally recognized that throughout the northern half of Africa, or even the whole of it, there is a widely diffused element of "White" blood, associated with the use of languages more or less closely related to the Hamitic group.[1] This stock appears historically in the Egyptians, Cushites, Libyans, Numidians, Berbers, and Guanches. It is now represented by the Berbers of the northwest and north coast, the Tawarek of the western Sahara, the Fula and Hausa of the western Sudan, the Bedauye east of the Nile, the Galla, Somali, Agau, Bilin, Saho, Khamir, Kafa, Bari, etc., around the "Horn" of east Africa, the Masai and Nandi in the lake region, and the Nama Hottentots in the extreme south. Even the great Bantu family may be the result of an early fusion of Hamitic with Negro.[2]

Although students of African linguistics and African ethnology have come to substantial agreement in the matter, as above outlined, and although resemblances between Hamitic and Semitic speech have long been recognized, Semitic scholars have uniformly maintained an attitude of doubt as to the character and direction of the relationship, holding that Semitic grammatical structure and morphology (there is little similarity in vocabulary) were widely borrowed by groups of Africans, the most conspicuous example being Old Egyptian.[3] I do not know whether the borrowers are supposed to have been Black or

[1] Von Luschan, *Völker, Rassen, Sprachen*, 1922; Keane, *Man, Past and Present*, rev. ed., 1920; Bates, *The Eastern Libyans*, 1914; Meinhof, *An Introduction to the Study of African Languages*, 1915; Meinhof, *Die Sprachen der Hamiten*, 1912.

[2] Meinhof, *opp. cit.*

[3] Brockelmann, *Semitische Sprachwissenschaft*, 1906.

White. The theory would seem to ignore the existence of the widely distributed Hamitic stock, or to make it of Semitic origin. Meinhof called attention to the characteristic Hamitic phenomenon of "polarity," or reversal of values in a two-class system,[2] to the development of the feminine grammatical category out of the "unimportant" category of that system,[2] and to the "pressure-articulation" in both Semitic and Hamitic speech:[4] in such a way as to show that outstanding psychological and phonetic peculiarities of Hamitic have passed on and developed further in Semitic. The present writer called attention to the application of the principle of polarity to the reversed genders of the Semitic digits, of the plurals and singulars, and of the intensives and anti-intensives;[5] and its application to the formation of the so-called "broken plurals."[6] It is well to continue to emphasize correspondences of this kind in the interests of a broader Semitic scholarship.

I therefore venture to offer three items: I. On the dichotomy underlying the imperfect tense in Semitic and Hamitic; II. On the identity of Semitic and Hamitic pronomial suffixes; III. On the evolution of counting in Semitic and Hamitic.

I

The oldest form of the Semitic imperfect is probably:

3 m. s.	ya-qtul	3 m. p.	ya-qtul-ū
3 f. s.	ta-qtul	3 f. p.	ya-qtul-ā
2 m. s.	ta-qtul	2 m. p.	ta-qtul-ū
2 f. s.	ta-qtul-ī	2 f. p.	ta-qtul-ā
1 2.	a-qtul	1 p.	na-qtul

Behind this is a still older system in which t is the sign of the "unimportant" category: "you" is secondary to "I" and "she" is secondary to "he." Afterward the 1 s. and 1 p. received special prefixes (derived from the corresponding pronouns?) to differentiate them from the 3 m. s. The 2 f. s. received a special

[4] *Zeitschrift für Eingeborenensprachen*, XI.

[5] *Journal of the Palestine Oriental Society*, I.

[6] *American Journal of Semitic Languages and Literatures*, XLI.

suffix to differentiate it from the 2 m. s. The remaining plurals received the suffixes ū and ā to differentiate them from the 3 m. s. and 2 m. s. respectively. In the 3 f. p., t was unnecessary, though it occurs.

Somali exhibits the following scheme, similar to the Semitic, but not derivable from Arabic:

3 m. s.	yi-mad-a	3 p.	yi-mad-a-an
3 f. s.	ti-mad-a		
2 s.	ti-mad-a	2 p.	ti-mad-a-an
1 s.	i-mad-a	1 p.	ni-mad-a

Evidently the dichotomy in both instances goes back to a time when dichotomy was essential, as it still is in Hamitic.

II

The pronominal suffixes of Old Egyptian are:

3 m. s.	f	3 p.	sn
3 f. s.	s		
2 m. s.	k	2 p.	tn
2 f. s.	t		
1 s.	i	1 p.	n

Of these the 2 m. s., 1 s., and 1 p. have long been recognized as identical with the Semitic. The remaining ones were supposed to be of non-Semitic, African, origin. They are, however, all plainly related to Semitic:

Semitic hu became ϕu by labialization, and then f;

Semitic hi (the separable pronoun) became χi by palatalization, and then s;

Semitic ki became ci by palatalization, and then t;

Semitic hin became χin by palatalization, and then sin;

Semitic kin became cin by palatalization, and then tin.

The second stage in the process of palatalization took place, as the orthography testifies, during the period of the Old Kingdom. A similar labialization and palatalization have taken place in Japanese since the establishment of its syllabary.

The essential relationship between Semitic and Hamitic in this instance cannot be doubted. Semitic preserves the more original forms, however.

III

Three stages in counting are represented by (1) Egyptian, (2) Ethiopic and Accadian, and (3) other Semitic languages. In Egyptian about half the digits have names corresponding to their names in Semitic;[7] and the highest common term is the highest of the digits, md, "ten." In Ethiopic and Accadian (Semitic languages) all the digits have their common Semitic names, and the same is true of the tens and hundreds, with some variation in form and manner of composition; and the highest common term is still m't (= md); but the word means now the highest of the tens (instead of the highest of the digits), "a hundred." Ethiopic has a word, elef, "very large number,"[8] "myriad." The other Semitic languages have gone a step beyond Ethiopic and Accadian, for they have taken the word elef (alif, etc.) and given it the value of the highest of the hundreds, "a thousand." This means that, before their separation, Hamites and Semites counted to "ten" only; at the time of the segregation of the Ethiopic[9] and Accadian groups the Semites counted to "a hundred" only; and before the "Canaanitish" Migration (*c.* 2500 B.C.) they counted to "a thousand."

The correctness of this theory of three periods in the evolution of counting is borne out by peculiarities of syntax in Semitic languages. Arabic has a singular, dual, lesser plural (up to "ten"), and greater plural (above "ten"). With the numerals "three" to "ten" dichotomy and polarity operate so as to place the numeral in the gender opposite that of the thing numbered. In the region between "ten" and a "hundred" and between "a hundred" and "a thousand" two other constructions prevail.

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[7] Originally fanciful names of the fingers?

[8] Noticed by Grimme, *Weltgeschichte in Karakterbildern*, 1904, p. 7.

[9] The Abyssinians are colonists from South Arabia.

A COMPARISON OF THE PERCENTAGES OF NON-DISJUNCTION IN SUCCESSIVE BROODS *

ERNEST G. ANDERSON

CROSSING-OVER in Drosophila has been shown to be influenced by such factors as age (Bridges, 1915; Plough, 1917, 1923), temperature (Plough 1917, 1923) and X-ray (Mavor, 1923; Mavor and Svenson, 1924; Muller, 1925, 1926). No comparable information has been available for non-disjunction, largely because the low percentage of exceptions in ordinary non-disjunctional lines of Drosophila makes it difficult to secure adequate data. In a high non-disjunction line arising from an X-ray experiment (Anderson, 1925), the percentage of exceptions is high enough so that significant figures can readily be obtained. While tests of other factors have not yet been made, the effect of age can be determined by a comparison of first and second broods from the same parents. This is of especial significance as it shows whether or not data from successive broods from the same parents may legitimately be combined.

The high non-disjunction line carried the recessive genes for crossveinless (13.7), vermilion (33.0) and forked (56.5) in the one X-chromosome and those for scute (0.0), echinus (5.5), vermilion and garnet (44.4) in the other $\left(\frac{cv\ \ v\ \ f}{sc\ ec\ \ \ v\ g}\right)$. The data on first and second broods from XXY females of this constitution are presented in Table I. Crosses made with scute echinus cut garnet gave cultures in which cut (20.0) and vermilion were also heterozygons. Tables II and III give corresponding

* Paper from the Department of Botany of the University of Michigan, No. 246, reporting research conducted by the author while holding appointment as National Research Fellow in Biology.

data for females of this constitution. Only those cultures are included in which there were at least one hundred individuals in each brood. A summary is given in Table IV. The first brood gave a percentage of exceptions of 23.66 and the second brood, 24.27. The deviation is only 0.61 ± 0.37. A deviation as great as that may be expected once in four trials because of the errors of sampling alone. Thus the data show no significant difference in percentage of exceptions between first and second broods in the high non-disjunction line under investigation.

The data on crossing-over in the same cultures are summarized in Tables V and VI. The deviations here are not greater than might be expected from the errors of sampling alone. These data are in accord with those of Bridges (1915) in showing no effect of age on crossing over in the X-chromosome.

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TABLE I

First and Second Broods from $\frac{cv\ v\ \ f}{sc\ ec\ \ v\ g}$ Females from High Non-Disjunction Line

Culture	First Brood							Second Brood						
	Total	Exceptions	Regular males	Crossovers				Total	Exceptions	Regular males	Crossovers			
				1	2	3	4				1	2	3	4
302	153	43	57	3	0	9	4	147	43	46	3	1	2	2
327	143	42	52	3	3	2	2	148	43	49	6	4	10	2
349	134	36	50	7	3	5	3	128	44	43	2	4	8	0
361	134	33	65	4	8	4	3	108	17	55	5	4	5	3
362	164	31	62	3	4	6	2	128	26	54	0	3	6	3
414	114	41	37	4	4	3	0	145	43	56	7	3	9	0
420	189	44	69	5	6	5	5	124	33	43	3	5	2	2
429	127	33	45	4	3	3	1	120	56	26	1	1	3	1
502	192	47	59	4	6	4	1	140	39	39	0	6	2	2
574	192	43	67	9	6	8	3	120	31	43	0	4	3	4
585	167	43	57	2	2	4	1	165	32	76	3	5	7	4
724	135	34	48	4	7	2	2	189	53	70	6	6	1	1
725	161	32	65	8	5	3	3	167	39	62	5	1	7	5
729	103	22	40	4	2	3	2	101	33	25	1	1	1	0
731	140	30	47	1	4	3	1	192	42	76	2	6	5	4
828	151	45	56	6	7	5	1	157	39	51	6	2	3	0
829	156	33	48	6	4	6	1	147	37	54	3	5	3	1
830	164	37	68	6	6	3	0	208	61	72	8	7	9	1
831	132	32	44	9	8	0	2	194	56	73	6	8	3	0
832	135	29	48	3	2	2	0	182	56	56	3	5	5	1
834	117	29	35	2	1	4	2	128	35	49	6	1	6	1
835	137	45	40	4	4	4	0	202	53	80	9	3	13	2
840	125	41	38	1	4	4	3	185	44	65	5	5	6	1
841	144	33	58	7	6	2	4	167	46	58	9	4	5	4
842	125	30	41	6	2	3	7	172	40	57	2	6	4	0
843	151	45	56	7	4	9	1	165	58	48	1	3	3	0
844	159	32	72	3	6	5	4	153	34	56	5	6	13	0
845	167	52	44	3	4	2	1	120	31	37	1	3	5	3
846	142	36	51	5	6	7	2	160	45	51	3	3	5	0
850	129	32	50	3	4	3	3	161	30	69	4	6	3	3
851	193	31	89	6	8	12	6	138	34	54	3	5	7	2
853	148	43	52	4	1	2	3	160	43	57	5	6	4	0
854	178	39	61	7	7	4	2	149	33	52	7	4	5	3
855	141	39	59	7	7	6	0	132	34	44	4	1	2	1
856	147	36	46	4	4	4	0	129	31	48	0	4	5	5
858	202	46	75	7	4	5	3	113	28	41	3	9	3	0
860	142	40	56	4	5	2	1	178	45	86	9	8	10	5
861	152	35	54	4	6	6	2	112	22	52	7	4	8	2
Total	5685	1414	2061	179	173	164	81	5734	1510	2073	153	162	201	68

TABLE II

First and Second Broods from $\frac{cv \quad v \quad f}{sc \quad ec \quad ct \quad g}$ Females from High Non-Disjunction Line

Culture Number	First Brood									Second Brood								
	Total	Exceptions	Regular males	Crossovers						Total	Exceptions	Regular males	Crossovers					
				1	2	3	4	5	6				1	2	3	4	5	6
43	117	27	48	2	2	1	2	1	3	257	60	91	12	5	2	1	2	4
48	160	33	61	6	4	4	2	1	9	141	25	57	8	4	4	3	0	1
57	184	41	68	7	2	1	1	3	2	114	34	33	4	1	2	1	2	1
307	202	41	77	6	13	5	4	0	7	132	16	45	5	3	3	0	1	2
316	179	39	74	11	6	5	0	1	1	129	29	51	3	2	0	0	1	7
320	197	38	72	5	6	2	3	1	3	167	52	59	3	4	3	1	1	3
326	153	31	45	0	5	2	2	2	3	192	32	73	6	6	3	1	0	8
376	197	40	72	4	9	3	2	0	5	141	23	59	2	6	3	0	1	5
378	219	58	81	5	7	4	4	0	1	163	51	51	0	10	3	1	0	2
500	232	50	88	8	8	5	2	1	6	258	42	101	9	8	5	3	1	3
580	198	42	75	1	4	5	0	1	10	216	31	97	3	10	5	2	0	5
583	207	47	75	4	8	3	2	0	4	192	51	62	6	3	2	2	1	3
660	166	46	58	8	3	5	2	0	7	176	56	58	5	6	1	0	2	4
742	162	27	60	6	5	6	1	0	4	188	38	77	3	4	2	1	0	3
762	178	46	69	8	5	2	3	0	4	156	32	61	10	5	1	2	0	0
780	189	42	71	9	6	2	1	1	3	174	35	73	5	4	3	2	0	4
787	142	43	38	5	4	1	0	0	3	125	28	44	5	5	2	2	0	2
788	166	36	74	7	3	4	4	0	6	144	28	47	3	4	1	1	0	1
796	199	42	85	6	7	6	5	0	3	173	35	68	5	4	6	2	0	3
810	153	40	57	4	3	5	2	0	2	140	33	53	3	3	5	1	0	1
812	130	27	48	7	6	1	2	0	0	138	36	57	4	4	4	1	0	3
813	138	41	45	3	4	0	0	0	2	189	48	75	8	5	5	0	0	0
819	154	35	62	2	9	4	2	0	6	123	39	37	4	4	3	1	0	1
826	127	28	52	6	5	8	1	0	1	184	62	63	11	5	3	3	0	0
865	180	54	62	5	6	4	1	1	4	110	27	46	6	0	3	1	0	3
866	222	44	91	12	13	6	1	1	5	115	32	45	3	3	2	0	1	5
867	169	39	57	5	2	11	1	0	4	101	26	31	3	2	0	0	2	2
870	137	33	47	3	3	1	0	0	1	110	24	35	2	2	2	0	0	1
884	160	28	53	3	2	5	0	0	2	186	31	69	3	8	5	0	0	1
889	148	43	59	3	2	1	3	0	4	151	23	55	6	6	3	1	0	2
Total	5165	1181	1924	161	162	112	53	14	115	4785	1079	1773	150	136	86	33	15	80

TABLE III

First and Second Broods from $\frac{cv \quad v \quad f}{sc\ ec \quad ct \quad g}$ Females Mated to *sc ec cv ct v g f* Males

Culture Number	First Brood Total	First Brood Exceptions	First Brood Regular	Crossovers 1	2	3	4	5	6	Second Brood Total	Second Brood Exceptions	Second Brood Regular	Crossovers 1	2	3	4	5	6
562	121	17	104	9	6	2	1	3	8	145	43	102	3	2	8	3	0	5
563	120	24	96	9	6	3	3	0	3	107	22	85	3	6	7	2	3	2
564	118	27	91	24	6	3	0	0	6	166	22	144	12	11	8	2	2	4
567	133	23	110	12	10	9	0	1	4	164	24	140	15	15	13	4	2	10
568	148	30	118	13	12	7	5	1	4	129	19	110	10	7	7	4	1	6
735	138	28	110	7	5	5	5	0	5	173	38	135	8	7	7	3	0	4
747	225	52	173	14	19	12	3	2	6	155	43	112	5	4	4	2	2	7
757	185	38	147	13	7	7	2	0	6	115	31	84	10	8	2	1	1	4
767	159	45	114	9	7	4	0	3	4	172	42	130	8	8	8	4	1	8
769	143	41	102	4	8	5	1	1	7	139	34	105	9	6	6	1	1	3
Total	1490	325	1165	114	86	57	20	11	53	1465	318	1147	83	74	70	26	13	53

TABLE IV

Summary of Data from Tables I to III on Non-Disjunction in First and Second Broods

Source	First Brood Total	First Brood Exceptions	Second Brood Total	Second Brood Exceptions
Table 1	5685	1414	5734	1510
Table 2	5165	1181	4785	1079
Table 3	1490	325	1465	318
Total	12340	2920	11984	2907
Percentage		23.66 ± .26		24.27 ± .26

TABLE V.

SUMMARY OF DATA FROM TABLES I TO III ON CROSSING-OVER IN FIRST AND SECOND BROODS

Region	First Brood		Second Brood		Difference
	Number	Percentage	Number	Percentage	
Total	5150		4993		
sc–ec	454	8.82 ± 0.27	386	7.73 ± 0.26	– 1.09 ± 0.37
ec–cv	421	8.17 ± 0.26	372	7.45 ± 0.25	– .72 ± 0.36
cv–g	431	8.37 ± 0.26	444	8.89 ± 0.27	+ .52 ± 0.37
g–f	249	4.83 ± 0.20	201	4.03 ± 0.19	– .80 ± 0.28

TABLE VI

SUMMARY OF DATA FROM TABLES II AND III ON CROSSING-OVER IN THE REGION FROM CROSSVEINLESS TO GARNET

Region	First Brood		Second Brood		Difference
	Number	Percentage	Number	Percentage	
Total	3089		2920		
cv–ct	169	5.47 ± 0.28	156	5.34 ± 0.28	– .13 ± 0.40
ct–v	73	2.36 ± 0.19	59	2.02 ± 0.17	– .34 ± 0.25
v–g	25	.81 ± 0.10	28	.96 ± 0.09	+ .15 ± 0.13

EGGS AND YOUNG OF THE EASTERN RING-NECK SNAKE, *DIADOPHIS PUNCTATUS EDWARDSII* *

FRANK N. BLANCHARD

THE discovery of a place where ring-neck snakes could be procured in some numbers led the writer to try to find out what might be learned of their eggs and young by collecting the females, retaining them until oviposition and then keeping the eggs till hatching.

The work was begun at the University of Michigan Biological Station at Douglas Lake in Cheboygan County, Michigan, and completed at the Department of Zoölogy of the University of Michigan in Ann Arbor. It is a pleasure for the writer to record here his appreciation of the free use of facilities of the Biological Station that was granted him by Professor George R. La Rue.

The eastern ring-neck snake, *Diadophis punctatus edwardsii* (Merrem), is the best known species in the genus, and yet there is a conspicuous dearth of information on the subject of its eggs and young. Five ova were found in a specimen collected in the Catskill Mountains, New York, June 12, by Bicknell (1882, p. 123); and ten are reported in a female collected in Allegheny County, Pennsylvania, July 9, by Atkinson (1901, p. 148). Blatchley (1899, p. 546) reports the finding of eight eggs of this species in the latter part of September, 1898, in dirt thrown out from a quarry. Most of these eggs hatched within a week. The first record of egg-laying in this species is that of Ditmars (1907, p. 336). He reports that a specimen from Sullivan County, New York, kept for a month in captivity, laid three eggs on June 28. These hatched on August 8. These cases comprise,

* Contribution from the Biological Station and the Department of Zoölogy of the University of Michigan.

apparently, all the published references to the breeding habits of the species. A few records collected by the writer follow.

A cluster of eight eggs of the ring-neck snake was found by the writer on July 13, 1922, in a little cavity in damp sawdust under a heavy piece of old wood on the shore of Burt Lake in Cheboygan County, Michigan. A little concavity in the under side of the wood fitted over the eggs. Except for the removal of one egg the nest was left undisturbed. The intention was to photograph it, and watch its progress. There were no eggs left, however, when the place was visited a few days later. Their fate can only be conjectured. The single egg saved hatched on August 30, 31, or September 1, and settled the specific identity of the nest.

A set of two eggs of this species was found on July 23, 1925, by Margaret Drum, of the Biological Station of the University of Michigan. They were in a large, uprooted stump near Vincent Lake, Cheboygan County, Michigan. The eggs were end to end in a tunnel of about the diameter of the eggs, three or four inches from the surface of the log, in the spongy, rotted part just above the solid heart. The stump was well shaded by a young growth of maple in cut-over beech-maple land. The eggs had every appearance of having been laid for more than a week. The ends were slightly yellow, and the sides bulging (Fig. 9). These eggs are recorded below as Set 13.

Three eggs was the total complement of an average-sized adult collected in southern Michigan, May 21, by the writer.

The source of the material used in the present study was discovered by T. H. Langlois (1924, p. 606) in the summer of 1923 at Big Stone Bay in the State Game Refuge in Emmet County, Michigan. Lifting a large board, or plank, lying in the short grass close to the beach of Lake Michigan (Fig. 2) on the third of August, 1923, Langlois uncovered nine ring-neck snakes. Lifting of the same board by Langlois or the writer on different days during the same and the subsequent seasons nearly always revealed one or two ring-neck snakes. A pile of boards from a fallen shack near by (Fig. 1) also was the source of from one to three ring-neck snakes on several occasions. On June 19, 1925,

the writer collected seven ring-neck snakes under the well-known board, four under the pile of boards, and six more close by in a pile of old white cedar bark at the upper edge of the lake beach (Fig. 3). The last six were apparently all full-grown females. Of these seventeen individuals, twelve subsequently laid eggs, three were immature females, and two were full-grown males. Altogether forty-five ring-neck snakes were collected in this immediate vicinity in the three seasons, none of which, strangely enough, were very small individuals. To preserve the colony, fourteen adults, mostly females, were returned on August 5, 1925.

The full-grown females of the collection of June 19, 1925, were isolated the same day in separate wooden cages with sliding glass covers, and kept there until their eggs were deposited.

Laying. — Most of the females deposited their eggs between the 12th and the 16th of July. The extreme dates were July 3 and July 27. Table I gives a summary of these dates, including also those of a set of eggs raised by the writer in 1924 from a female collected at the same locality and those of the set discovered by Miss Drum, described above. In all but two instances the total complement of a female was deposited within one day. The two exceptional cases were the two eggs of Set 2, which were deposited on successive days, and gave rise to two abnormal young, as will appear below; and the second egg of Set 14, which was deposited two days after the first, and failed to hatch. It appears, then, that a normal complement of eggs is deposited within one day, and that the usual date in northern Michigan is the middle of July.

The number of eggs deposited by each female is, in the writer's experience, most commonly three or two, with a single instance of each of the numbers 1, 4, 5, and 8. Published records, enumerated above, are 3, 5, 8, and 10.

The actual deposition of an egg was observed only once. The parent of Set 11 was found at 6:30 P.M., July 19, with one egg, evidently freshly laid. The writer put the cage containing this snake on the desk beside him, intending, while doing some other work, to watch for the deposition of the next egg. At 7:23 P.M. another egg was found which was not fully opaque,

indicating that it had just been deposited. At 8:10 P.M. she began to raise the tail at its base, or proximal end. A minute later the third egg appeared in the vent. In three more minutes it was wholly out. During the extrusion, the tail was arched well up and to the right side, and the anus was pulled forward off the egg. The tail remained highly curved for about 20 minutes more. During the laying the body of the snake was in a double circle, one coil directly over the other, with the head above and pushed to one side into the sawdust. The egg was laid inside the coils and close to them. Movements of the body had pushed the sawdust aside all around, leaving the snake in a circular cavity, with the eggs all within her coils.

That this position of the body of the female is the usual one is indicated by the fact that several of the sets of eggs were found thus within the coils of the parent's body. Figure 4 shows the parent of Set 14 in approximately this position, just after deposition of her first egg. The anterior half of her body is extended away, largely under the sawdust except for the head. The parent was also found coiled about the eggs in Sets 6, 9, and 12. In no case was a female observed to return to a set of eggs after she had once left it.

The position within the group of the eggs of a complement is variable. They may be more or less stuck together, or all separate. If a freshly laid egg comes in contact with another egg it sticks to it. The movements of the body of the female between the layings of the eggs are sufficient to disarrange the eggs already laid, and sometimes even to thrust an egg outside the body coils. The eggs are usually morphologically separate, but in two instances eggs were found connected by a thread-like strand between their ends. This is well shown in the photographs of the eggs of Set 10 (Figs. 11–15). The connection persisted in this case until after all the eggs had hatched.

Eggs. — Just after deposition the eggs may be described as elongate, straight or curved, with ends blunt or slightly pointed. This is shown in Figures 4, 5, and 11. They are cream-colored with distinctly sulphur-yellow ends. Occasionally the yellow is more extensive, and may suffuse the whole surface. This yellow

gradually fades, until, towards the latter part of the incubation period, it disappears completely. The cream color of the rest of the egg likewise becomes much duller, and the surface may become variously stained from contact with external materials. The eggs vary in length from 21.0 to 33.3 millimeters, and in width from 6.7 to 8.8 millimeters. The lengths of the eggs in a single set are rather uniform, but considerable variation may occur (see measurements of the eggs of Set 8, Table II). The eggs just after deposition are not fully plump, but are transversely wrinkled, as shown in Figures 5 and 11. If an egg is held to the light, the embryonic circulation shows plainly in its middle.

After deposition the eggs swell. In a day or two they are fully plump. In a few days they have increased a millimeter or two in length and in width. In one or two weeks the shape has changed decidedly: the ends are relatively more pointed and the middles are irregularly distended (compare Figures 6, 9, 10 and 12). This change in shape was first noted by Ditmars (1907, p. 336). The increase in length and width is more rapid in the first few weeks, but continues until within a week or so of hatching. Increase in size may then cease or the egg may show a slight decrease in dimensions. The eggs of five sets that passed through the usual incubation period of seven to eight weeks showed at the end of successive weeks average total increases in length as follows: 4.4, 5.7, 7.5, 9.0, 11.2, 12.2, and 12.1 per cent. The variation in percentage of increase in length at the end of the first week is from 3 to 9, at the seventh week, from 7 to 21, and is similar in the weeks between.

The eggs observed by the writer were all kept in small closed containers surrounded by very slightly damp sawdust. Some of them, when exposed to the air for measurement or photographing, split, and some of the liquid contents oozed out. An instance is shown in Figure 9. Such eggs were returned immediately to their sawdust, and invariably healed their wounds so well that they could not later be detected.

The incubation period, that interval from deposition of the egg to emergence of the young snake, showed considerable variation, from one brood to another, but, in most cases, all the

eggs of a set hatched in the same number of days. Forty-six days is the shortest interval recorded and 60 days the longest. Most of the eggs hatched in from 51 to 54 days. The eggs recorded by Ditmars, however, hatched in 41 days (1907, p. 336). Examination of the incubation periods in Table I shows that for the eggs hatched in 1925 there is a tendency for the eggs laid earliest in the season to have the longest period of incubation. This and the fact that the eggs of a set usually have the same incubation period make it probable that the gestation period, or interval from fertilization of the egg to its hatching, is a rather definite one, but that the laying takes place at varying stages of embryonic development. It would be interesting to know what the stimulus is that causes the female to deposit her eggs.

Hatching. — The hatching of most of the eggs of the 1925 sets took place from August 28 to September 5, but one egg hatched on September 11 and four eggs of a 1924 set hatched from September 20 to 22. These dates are listed in Table I. Out of forty-one eggs that were cared for, thirty-two hatched, a percentage of 78.

The process of hatching was always prolonged for several hours. This period, from the cracking of the shell to the complete emergence of the young snake, may be called the emergence interval. This could not be timed exactly for all the eggs as it would have required constant observation day and night. In several cases, however, more or less definite intervals were obtained as follows: 15 hours, 17 minutes; 15 hours, 47 minutes; $16\frac{1}{2}$ to 19 hours; $15\frac{5}{6}$ to $19\frac{1}{3}$ hours; $16\frac{2}{3}$ to $19\frac{1}{6}$ hours; 19 to 20 hours; $22\frac{1}{2}$ to 23 hours; $24\frac{1}{2}$ hours; and more than $27\frac{1}{4}$ hours. This shows that after the egg is cracked it may be expected that nearly a day will elapse before the young snake comes entirely out.

Cracking of the shell seems to be produced by the thrusting movements of the head or the turnings of the body of the snake. A small "egg tooth" is present, and this may, of course, be partly responsible for the first break in the shell. A large drop of clear liquid first flows out. This is imperfectly shown in egg No. 2, Figure 14. Here the first slit has appeared, the clear

drop has flowed out, and the movements of the snake within the shell have caused this egg to be a little blurred in the picture. Within a few minutes at most the tip of a snout appears in the opening or in a new opening near by. Typical cases are shown in egg 2, Figure 7, egg 3, Figure 13, egg 1, Figure 15 and eggs 2 and 3, Figure 16. The young snake may rest for a long time in this position, but most of the waiting is done with the snout projected far enough to expose one or both eyes (Figs. 7 and 16). The head may be withdrawn for a time and later projected through the same or a new opening. As the time for emergence approaches, the snake becomes more active; the head is projected farther and is more sensitive to external stimuli (Figs. 17 and 18). When the snake has emerged as far as shown in Figure 8, he usually comes slowly and steadily all the way out. The moisture rapidly dries from his body, and he crawls away as though he had long been accustomed to the external world.

The young snakes. — These little snakes, when just out of the egg, present a beautiful, trim appearance. They are nearly black above, and shiny, with the top of the head still blacker, the neck ring pale orange-yellow, and the belly pinkish and translucent. By comparison with Ridgway's *Color Standards*, more of the individuals examined were slate color than any other color. Variations extended from dark plumbeous to plumbeous-black, and dark neutral gray to slate-black. The neck ring was most commonly about maize-yellow, but varied to orange-buff on the one hand and to ivory-yellow on the other. The belly color was, because of its translucency, variable on each individual. Its general color range was from pale salmon to flesh-ocher.

In a few days the belly becomes opaqüe and buffy in color. The upper surfaces become gradually duller and on about the seventh day the skin is shed. Three individuals were recorded as shedding on the fifth day, six on the sixth, sixteen on the seventh, one on the eighth, and one on the ninth.

Now, after shedding, the young snakes are still further improved in appearance. The color above is a velvety-black, with the top of the head still blacker, the neck ring a brighter yellow or orange-yellow, and the belly shiny-cinnamon or buff.

In terms of Ridgway's *Color Standards,* the dorsal coloration of most of the specimens was slate-black, but varied to dark neutral gray and plumbeous-black. The neck ring varied from apricot-yellow to deep chrome on the one hand and to baryta-yellow on the other. The lower surfaces were commonly about clay color with variations to zinc-orange and buckthorn-brown.

In proportions the young snakes are not noticeably different from the adults. They vary in length from 115 to 143 millimeters. These measurements were taken on etherized or killed individuals. When they are taken on the living snake, somewhat greater variation is shown, but the tendency in this case is to stretch the snake a little.

The little snakes climb and explore about rather actively. What their food may be in nature is a puzzle. They showed no interest in earthworms, sowbugs, crickets, caterpillars, beetle larvae, small bugs, ants, ant pupae, ant larvae, spiders, and slugs. But introduction of a small, year-old red-backed salamander (*Plethodon cinereus*) caused immediate interest, and one snake ate it. This was repeated later in two instances, and once a young snake ate the writhing, separated tail of an adult Plethodon. A small newt, however, failed to elicit interest. Surely young ring-neck snakes cannot depend upon a supply of very small plethodont salamanders.

Most of these young ring-neck snakes lived in the laboratory about eight weeks without feeding and without becoming noticeably thin. It is, therefore, quite possible that, in northern Michigan, the snakes of this species may enter upon their first winter's hibernation before taking food.

Abnormalities. — A few abnormalities of more than passing interest appeared. All the eggs of normal sets were deposited on the same day. Such eggs did not invariably all hatch. But when the eggs of a complement were laid on different days, they either did not all hatch, or gave rise to abnormal individuals. An example of the first condition is the second egg of Set 14, which was deposited two days after the first and failed to hatch. The three cases of abnormal individuals from eggs laid on separate days require a more lengthy treatment. The two eggs

of Set 2 were deposited on successive days and much earlier than any of the other sets. These eggs hatched on successive days, after an interval of fifty-six days, and gave rise to the most abnormal type of scalation the author has seen on any snake. In both specimens, although the dorsal scales are in 15 rows, as is usual, they are mostly fused with each other, end to end, giving a strikingly odd, clapboarded appearance; the ventrals are nearly all divided in the midventral line; the caudals are irregularly fused, end to end; the head scales are also irregular and different in the two individuals. In No. 1 the labials are irregularly fused, particularly in the upper row; a minute extra lower preocular is present; the temporals are increased in number; a long, narrow azygous scale is present between the prefrontals, and a small one lies medially just behind the frontal. In No. 2 the upper labials are 8, but there is a series of narrow scales on the lower side of most of the series; the lower labials are 7 or 8, but irregular; there is a very minute extra lower preocular, and the normal one is fused with the loreal; the upper loreal is very small; a small azygous scale lies between the internasals and prefrontals. Both snakes have a crook at the tip of the tail. Both were very sluggish in disposition.

Another abnormal individual hatched from one of the eggs of Set 7. The other eggs of this set failed to hatch. The records show that this set of eggs was laid by the parent of Set 2, but as there is some doubt on this point they have been listed separately. This snake is the smallest one hatched from any set. The scales are noticeably irregular and number 11 or 12 rows, mostly 11 rows. The loreal is fused with the lower preocular; the sixth upper labial is in contact with the parietal. This individual was noticeably shiny in appearance.

Another abnormality concerns the failure to lay an egg. One adult showed an enlargement that was evidently a single egg. It was retained in the ordinary position in the body until September. On the third of that month the egg was down next to the vent, with the body anterior to the egg shrunken and ridged. The egg was not laid, however, but was in the same position the next morning. In the early afternoon the snake was dead.

Dissection showed that the egg was in the posterior end of the right oviduct. It was somewhat shrunken and hard in the middle, showing that the embryo had died in an early stage of development. It seems probable that the death of the embryo was responsible for the failure of the stimulus to deposit the egg at the usual season, as well as for the final failure of deposition, and for the death of the snake.

SUMMARY

1. The eastern ring-neck snake deposits commonly three or two eggs. There are records of complements of one, four, five, eight, and ten.

2. The eggs are deposited about the middle of July in northern Michigan. Extreme dates are July 3 and July 27. There is a record for southern New York of June 28.

3. The eggs of a complement are normally deposited within a few hours.

4. At deposition the eggs are cylindrical, straight or curved, with blunt or slightly pointed ends. After a few days they become somewhat irregularly distended and increase slowly in length and girth.

5. At first the eggs are of cream color with sulphur-yellow ends, but after a few weeks the yellow disappears, and the eggs take on various stains from surrounding substances.

6. Hatching occurs commonly in from 51 to 54 days, but extremes of 46 and 60 days were observed, and one writer records 41 days.

7. The dates of hatching vary from August 28 to September 22, but most of the eggs hatch from August 28 to September 5.

8. Emergence from the egg requires from 15 to 27 hours.

9. The young snakes are shiny and nearly black above; the neck-ring is pale orange-yellow, and the belly is pinkish and translucent.

10. The skin is first shed on about the seventh day. The color above is then about the same as before, but more velvety in appearance. The belly, however, becomes cinnamon in color and opaque.

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TABLE I

SUMMARY OF EGG-LAYING AND HATCHING

Set number	Egg number	Date of laying	Date of emergence of young	Number of days of incubation	Number of days to first shedding of skin	Number of eggs in set	Number hatched
1		July 23, 24*	Sept. 20–22	59–60		5	4
2	1	July 3	Aug. 28	56	6	2	2
	2	July 4	Aug. 29	56	7		
3	1	July 12	Sept. 2	52	5	4	3
	2	July 12					
	3	July 12	Sept. 2	52	6		
	4	July 12	Sept. 1	51	5		
4	1	July 12	Aug. 31	50	5	3	3
	2	July 12	Aug. 31	50	6		
	3	July 12	Sept. 2	52	6		
5	1	July 12	Sept. 3	53	8	3	3
	2	July 12	Sept. 3	53	6		
	3	July 12	Sept. 3	53	7		
6	1	July 12				3	2
	2	July 12	Sept. 4	54	7		
	3	July 12	Sept. 4	54	7		
7	1	July 14				3	1
	2	July 14	Aug. 31	48	9		
	3	July 14					
8	1	July 14	Sept. 4	54	7	3	3
	2	July 14	Sept. 4	54	7		
	3	July 14	Sept. 4	54	7		
9	1	July 16				2	1
	2	July 16	Sept. 5	51	6		
10	1	July 16	Sept. 5	51	7	3	3
	2	July 16	Sept. 5	51	7		
	3	July 16	Sept. 5	51	6		
11	1	July 19	Sept. 4	47	7	3	1
	2	July 19					
	3	July 19					
12	1	July 21	Sept. 5	46	7	3	3
	2	July 21	Sept. 5	46	7		
	3	July 21	Sept. 5	46	7		
13	1		Aug. 29		7	2	2
	2		Aug. 29		7		
14	1	July 25	Sept. 11	48	7	2	1
	2	July 27					

* This is a 1924 set, the rest are 1925.

TABLE II

MEASUREMENTS OF THE EGGS OF SET 8

Date	Lengths in millimeters			Widths in millimeters		
	Egg no. 1	Egg no. 2	Egg no. 3	Egg no. 1	Egg no. 2	Egg no. 3
July 14	26.7	25.0	27.6	7.3	8.0	7.5
July 15	27.1	25.7	28.1	8.2	8.7	8.0
July 19	27.4	26.2	28.3	8.6	9.3	8.0
July 26	27.8	26.9	28.4	9.3	10.0	9.0
Aug. 2	28.2	27 2	28.3	9.9	11.1	9.2
Aug. 9	29.0	28.1	29.0	9.9	11.1	9.3
Aug. 16	29.1	29.0	29.3	10.0	12.2	10.3
Aug. 23	30.0	29.1	29.2	10.3	12.7	10.2
Aug. 30	29.8	29.5	29.2	10.7	12.1	9.8

EXPLANATION OF PLATES

PLATE XIII

FIG. 1. Pile of boards near beach of Lake Michigan, State Game Refuge, Emmet County, Michigan. Snakes of several species were found under these boards on numerous occasions.

FIG. 2. "The Board in Emmet County," State Game Refuge, Michigan, under which many ring-neck snakes have been found.

PLATE XIV

FIG. 3. Pile of white cedar bark, close to the sites shown in Figures 1 and 2, where several adult female ring-neck snakes were found.

FIG. 4. Fresh-laid egg, Set 14, with posterior half of parent's body coiled about it in the usual position. Nearly twice natural size.

PLATE XV

FIG. 5. Fresh-laid eggs of Set 7, about natural size.

FIG. 6. Eggs of Set 7 nineteen days after laying. About natural size.

FIG. 7. Egg 2 of Set 7 beginning to hatch. Nearly natural size.

Fig. 8. Eggs of Set 7 photographed a little later than in Figure 7, to show the young snake emerging from the egg. Nearly natural size.

PLATE XVI

Fig. 9. Two eggs, Set 13, collected July 23, 1925, near Douglas Lake, Michigan, by Miss Margaret Drum. Photographed August 2. Egg No. 1 burst while being photographed and its contents began to ooze out. (It was promptly returned to damp sawdust, and healed perfectly.) The reproduction is about natural size.

Fig. 10. Eggs of Set 11 photographed thirteen days after they were laid. Nos. 1 and 2 are stuck together. About natural size.

Fig. 11. Eggs of Set 10 photographed on day of deposition, July 16, 1925. About natural size.

Fig. 12. Eggs of Set 10 photographed on August 2. About natural size.

PLATE XVII

Fig. 13. Eggs of Set 10 on September 4. No. 3 is beginning to hatch. Nearly twice natural size.

Fig. 14. Eggs of Set 10 photographed to show No. 2 beginning to hatch. A crack has appeared and a large drop of the fluid contents has flowed out. The movements of the young snake within the egg have caused its outline to be blurred. About twice natural size.

PLATE XVIII

Fig. 15. Eggs of Set 10 taken a little later than in the last figure. The young snakes have left eggs 2 and 3, and egg No. 1 has begun to hatch. Nearly twice natural size.

Fig. 16. Eggs of Set 12, showing Nos. 2 and 3 beginning to hatch. About twice natural size.

PLATE XIX

Fig. 17. Typical view of a Diadophis egg hatching, viewed from the side.

Fig. 18. Hatching of one of the eggs of Set 1. Ventral view of the young snake.

PLATE XIII

FIG. 1

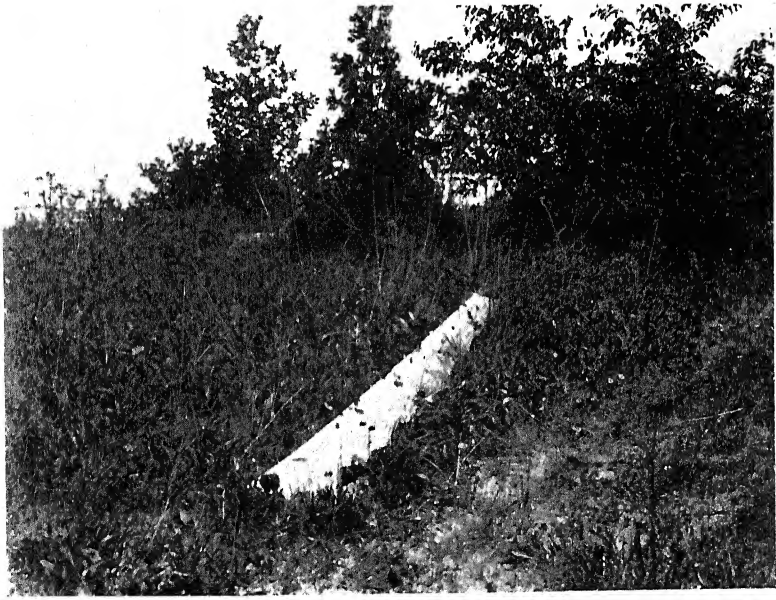


FIG. 2

PLATE XIV

Fig. 3

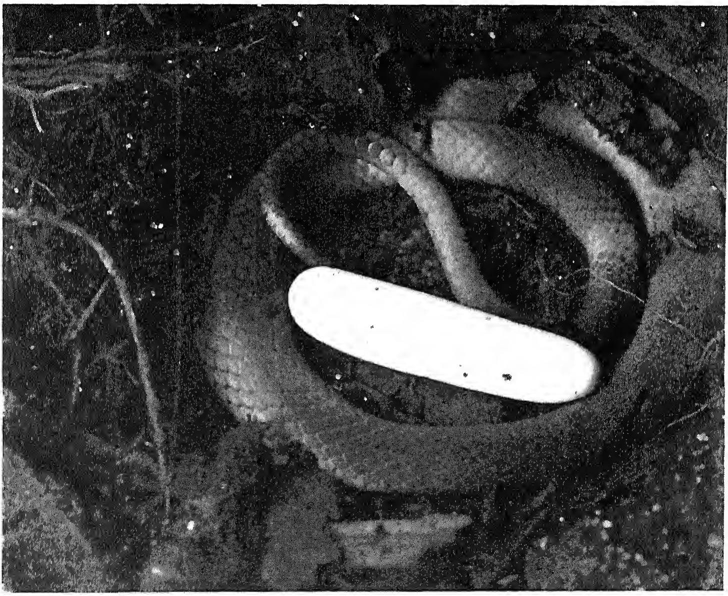


Fig. 4

PLATE XV

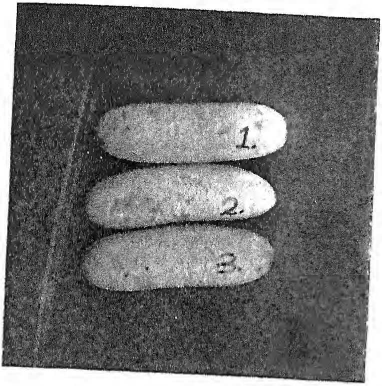


Fig. 5

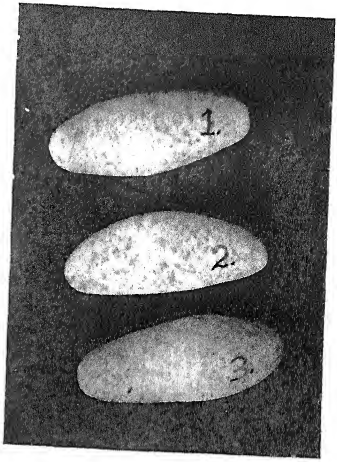


Fig. 6

Fig. 7

Fig. 8

PLATE XVI

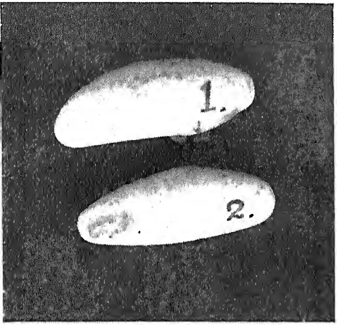


FIG. 9

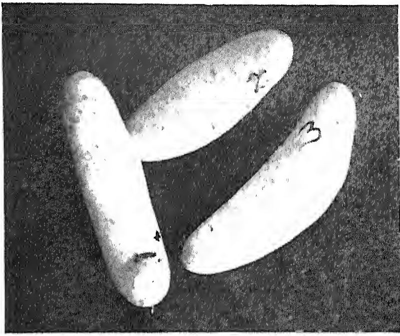


FIG. 10

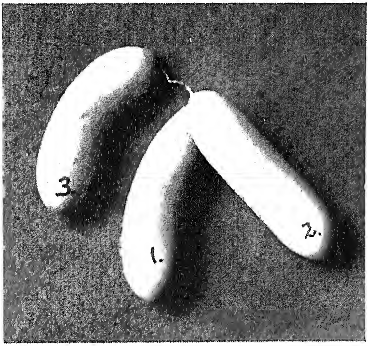


FIG. 11

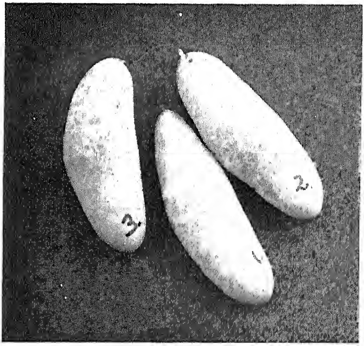


FIG. 12

PLATE XVII

Fig. 13

Fig. 14

PLATE XVIII

Fig. 15

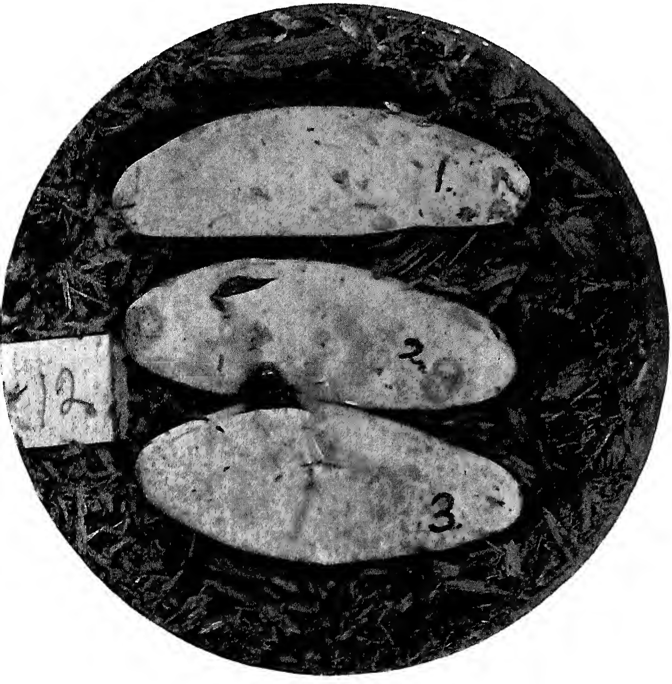


Fig. 16

PLATE XIX

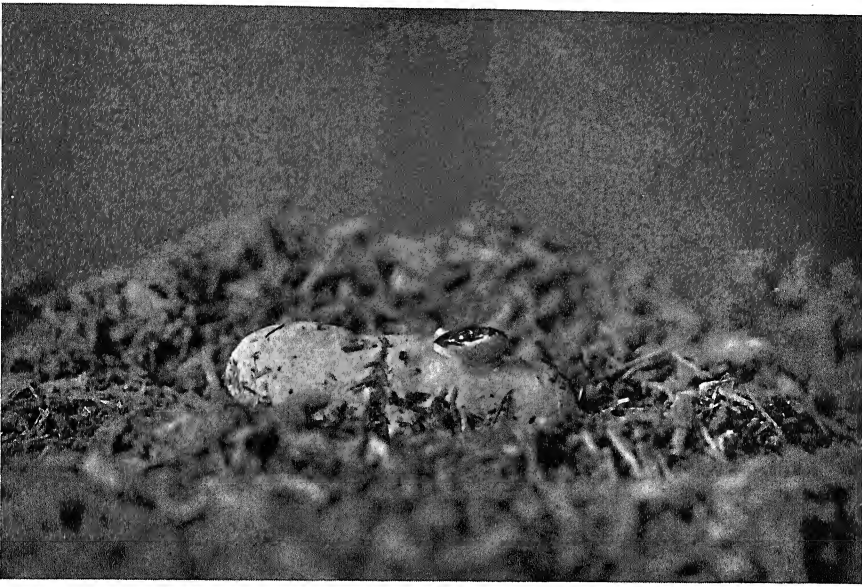


Fig. 17

Fig. 18

A SMALL COLLECTION OF MAMMALIAN REMAINS SECURED BY THE UNIVERSITY OF MICHIGAN EGYPTIAN EXPEDITION *

ROBERT K. ENDERS

THE mammalian remains described in this paper were discovered during the excavations conducted in Egypt by Professor A. E. R. Boak of the University of Michigan. I am indebted to him for the following paragraphs describing the conditions under which they were found.

"During the winter 1924–25, an expedition representing the University of Michigan was engaged in excavating the mound of Kom Aushîm on the northern border of the Fayûm province of Egypt (see Map 7). This mound was formed by the ruins of the ancient town of Karanis, a colony founded by the Ptolemies, the Greek rulers of Egypt, about the middle of the third century B.C. The life of this town lasted for about seven hundred years or until it was abandoned in the middle of the fifth century after Christ, owing to the neglect of the canals upon which its population depended for the irrigation of their fields and consequently for their livelihood.

"The object of the expedition was to conduct a systematic excavation of this site with the purpose of reconstructing the various phases of its history. As the history of Karanis was typical of that of a large number of other towns in this same district, the recovery of its life-story would shed a great deal of light upon the history of the whole of the Fayûm during this period. Accordingly, in its widest sense the scope of the expedition was the recovery of the civilization of the Fayûm during the period of Greek and Roman domination in Egypt.

* This paper was presented before the Section of Anthropology.

"To make this picture complete one must know not merely the system of provincial and local government under which the people lived, their art and architecture, their religion and customs, but also the crops which they raised and the flocks and herds which they tended, as well as the wild animal and vegetable life with which they came into contact. It was for this reason that all plant and animal remains found in the course of the excavations were carefully preserved with a record of their location, so that the period to which they belonged could be given with approximate accuracy. These botanical and zoological specimens were brought back to the University for identification by the experts of the departments concerned and this paper contains a partial report of the work accomplished so far on the animal remains. The specimens reported upon here all belong to the period between the middle of the second and the middle of the fourth century after Christ."

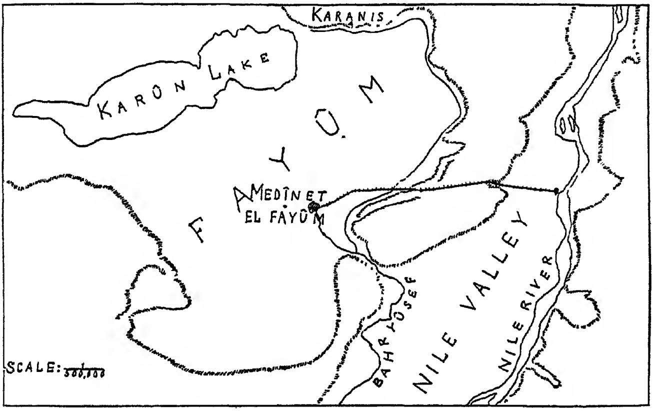
The mammals represented in this collection are the gazelle, hartebeest, pig, domestic cow, horse, ass and sheep. Some of the remains are probably of goat, but no specific determination has been made of either the sheep or the goat. These mammals fall naturally into two groups, the wild and the domestic, and will be so treated in this paper.

Of the remains of wild animals, there are five horns representing two species. Both of these species are antelopes, one being a small antelope, *Gazella dorcas*, an animal of wide distribution in North Africa today. The second is a hartebeest of the genus or subgenus Alcelaphus. Without more comparative material it is not possible to make a specific determination of this form, for there are no fewer than seven species known, but it may be Lichtenstein's hartebeest. It is interesting to note that, while the hartebeest is "the most abundant game animal in East Africa" and is now "abundant throughout Central and Southern Africa," it is not found in North Africa.

The pig may be placed in the domestic group, as the remains of three at least can be assigned to *Sus scrofa*. It is to be remembered, however, that there are no characters by which the wild and domestic pig may be separated positively. At an early

date *Sus scrofa* was distributed over all North Africa and it is still found wild there in many localities. A series of fourteen measurements of a perfect skull corresponds with a similar series made on a skull of a wild boar from Tunis, showing this pig to be of a type approaching, if not identical with, the present wild pig of Tunis and North Africa.

Of the domestic animals the cow presents the most interesting distribution. The skull of the single specimen is incomplete,



MAP 7. Sketch map of the Fayûm, showing the location of Karanis, the site of the University of Michigan excavations of 1924–25

but it can be assigned tentatively to the domestic race *Bos taurus macroceros*. This is a large-horned primitive breed which during prehistoric and early historic times ranged from the Indus across Mesopotamia into southern Asia Minor and the Balkans.[1] There was a small break in the distribution in Syria due to local conditions, but the race ranged to the Nile Valley and down it to the Sudan. At present *Bos taurus macroceros* is not found anywhere in its old range except in the Balkans, but is scattered over Europe and Asia from Spain to Manchuria, down to Indo-China

[1] Duerst, J. U. *Animal Remains from Excavations at Anau.* Carnegie Institute of Washington, Publ. 73, Vol. II, Map 3.

and India. The Sudan, where it did not occur in early historic times, now supports it in numbers, but the race is lacking in the Nile Valley, where it was formerly the chief domestic race. This skull fragment represents the old Egyptian long-horned race.

The genus Equus is represented by a complete skull of a horse and by the anterior portions of the maxillaries of an ass or half-ass. The latter material is too fragmentary to enable the writer to say more about the animal, but the skull of the horse is so well preserved that a large series of measurements were made for comparison with other horses. That the skull is that of a horse instead of that of an ass or half-ass is shown by the typical elongation of the entire skull with relatively large diastemas, the usual compactness of the ass's skull being replaced by this elongation. Moreover, the molariform teeth, though much worn and though broader than long, show that the ratio is within that assigned to Oriental horses. The measurements indicate that the animal was slightly smaller than the typical Arab, but this is probably not significant, for there is great individual variation in size among the horses. The enamel plications are considerably smaller than in the western horses. Ignoring the characters that are of doubtful value in determining the breed, the writer believes the skull to represent a rather small horse of Oriental origin and related probably to the Arab, belonging to the desert type of broad-faced horses, but having no relation in historic time with the narrow-faced type of Europe.

The Material

Gazelle, *Gazella dorcas.* — Of the gazelle there are four complete horns excellently preserved but no skulls or teeth. These horns show great variation in size. Both male and female are represented.

Hartebeest, *Alcelaphus sp.* (*Bubalis lichtensteini*). — A single horn of large size with the horn core in place and a small portion of the frontal bone attached are the only material in the collection from this species.

Pig, *Sus scrofa.* — Of this species the material is most abundant, consisting of one almost perfect skull from which only a

few incisor teeth are missing, a right lower jaw with all molariform teeth intact, and another specimen represented by a single molar tooth. Some measurements made on the skull gave the following results:

Length from middle of occipital ridge to line of juncture between anterior borders of orbits	114 mm.
Greatest width of frontal bone	99 mm.
Width between anterior border of orbits	68 mm.
Lower jaw	
Length of symphysis	67 mm.
Width of corpus between exterior borders of alveoli of tusks	49 mm.
Width between inner borders of same	33 mm.
Height of horizontal branch before premolar 3	39 mm.
Width of ascending branch of ramus	74 mm.

Cow, *Bos taurus macroceros* (Duerst). — A well-preserved posterior portion of a skull with a portion of the horn cores and frontal bones, and one horn from another individual are all the remains of this race in the collection.

Circumference of horn core at base, right	57 mm.
Circumference of horn core at base, left	58 mm.
Width of foramen magnum	44 mm.
Width above condyle	99.6 mm.

Horse, *Equus caballus* subsp. — An almost complete skull with but few teeth missing. The skull is that of a very old individual.

Length of base of skull	462 mm.
Length of face	510 mm

Ass or **Mule,** *Equus sp.* — The anterior portion of the maxillaries with the incisor and canine teeth intact. The short diastema is that of an ass or half-ass. Even in this fragment the foreshortening is evident.

Dog, *Canis familiaris.* — A single well-preserved cranium is clearly that of a large dog, probably of Asiatic origin.

Sheep, *Ovis sp.* — The skulls of two immature individuals in an excellent state of preservation are in the collection. In addition to this material there are some horns and horn cores also.

Goat, *Capra sp.* — A few horns represent this species.

The material is being preserved in the Museum of Zoölogy

of the University of Michigan for the present. It will doubtless be supplemented by other finds of future expeditions. Because of the difficulty of making specific and subspecific determinations in the field, all skulls and teeth, no matter how small, and all horns would prove useful to the museum worker in making comparisons and identifications. Even broken limb bones and similar fragments, though of less value, would be helpful. As soon as a large series has been identified, it will be of great aid in all future research and will form a nucleus for a comprehensive collection upon which anyone could work.

In conclusion I wish to acknowledge my indebtedness to Professor A. E. R. Boak for aid in this work as well as for the opportunity to study the remains; to Dr. L. R. Dice for constant encouragement and help; and to the U. S. National Museum for assistance and the use of their splendid collections.

University of Michigan

AN ICHTHYOLOGICAL SURVEY OF WISCONSIN *

C. WILLARD GREENE

THE Ichthyological Survey of Wisconsin has been carried on in the past, as at the present time, almost exclusively in connection with the Wisconsin State Geological and Natural History Survey. Much of the material which has accrued from various special collections of fishes has been incorporated with the Survey collection; there is much, however, which is not included. Some of this material will be found in collections listed below; some of it I have not been able to trace.

EARLY WORK OF THE SURVEY, 1905–22

Professor George Wagner, of the Zoölogy Department of the University of Wisconsin, has had charge of the collection until recently. During the summers of 1905, 1906, 1907, 1908, 1909 and 1911, he himself made extensive collections from various locations in the state, notably from lakes Mendota, Menona, and Wingra, near Madison, and from Lake Pepin on the Mississippi River on the Wisconsin-Minnesota line.

Other important collections have been made in connection with the Survey from time to time, largely from lakes, rather than from streams or rivers. Mr. H. H. T. Jackson made collections, with especial attention to the coregonid fishes, in Vilas, Iron, and Bayfield counties (Lake Superior drainage basin) in the summer of 1909; Dr. A. S. Pearse, from the lakes near Madison in 1914 and 1915, and from lakes Pepin, Geneva and Michigan, and a few other smaller ones, in 1920; Dr. A. R. Muttkowski,

* A preliminary report of work carried on coöperatively by the Wisconsin Geological and Natural History Survey and the Museum of Zoölogy of the University of Michigan.

from the lakes near Madison in 1914 and 1915; Dr. John N. Lowe, from Sturgeon Bay, in 1914; Dr. Alvin R. Cahn, from Oconomowac Lake in Waukesha County (1914, 1915, 1925, and possibly other dates).

Mr. W. Marshall and Mr. N. C. Gilbert (1902 and 1903) had an extensive collection at their disposal for their studies of the food and parasites of fresh-water fishes. This material was from the lakes near Madison, but is not now preserved.

Dr. Walter Koelz, of the Bureau of Fisheries, collected along the Lake Michigan shore of Wisconsin in 1920 and 1922. He paid particular attention to the Coregonidae, and a large part of his material is deposited in the Museum of Zoölogy.

Mr. Carl L. Hubbs and Mr. L. L. Pray collected at Lake Pepin in the fall of 1917, for the Field Museum of Chicago.

THE LATER WORK OF THE SURVEY, 1924–25

Early in 1924, mainly because of the interest and efforts of Mr. Hubbs and Professor C. Juday of the Biology Department of the University of Wisconsin, the ichthyological branch of the State Survey was reorganized. At this time Dr. C. L. Turner, professor of zoölogy at Beloit College, Wisconsin, kindly offered to collect fishes in connection with his own work. He made an extensive collection in that summer, principally from the streams of the Lake Michigan drainage basin in the southeastern part of the state.

Late in 1924 a special arrangement was made by the Survey to provide for the expenses of extensive field-work for the following four years, with plans for the preparation of a detailed report on the fish fauna of Wisconsin at the end of that time. This work was to be done, and reported upon by, or under the direction of, Mr. Carl L. Hubbs, curator of fishes at the University of Michigan.

Under this active stimulus, the summer of 1925 was a productive one, five different expeditions making collections of fishes for the Survey. Professor Peter Okkelberg, of the University of Michigan, on a trip across the northern part of the state, collected at various points along his route; Dr. H. T.

Folger, also of the University of Michigan, in the northeastern part, principally in Forest County; Dr. Jan Metzelaar and T. H. Langlois, of the Michigan Conservation Department, from Vilas County in the northern part. Professor Turner also collected, but, unfortunately, his material was lost. The writer and an assistant spent ten days collecting in the Fox River basin (Green Bay drainage), in Columbia, Marquette and Green Lake counties; on this trip a new subspecies of *Notropis nux* was secured.

As a result of this work, the Survey collection includes almost two thousand lots of fishes, with from one to several hundred specimens in each lot. Each lot is accompanied by accurate data, though the information, particularly with regard to ecological data, is not always as comprehensive as might be desirable.

At the present time all the material of the Survey is in the Museum of Zoölogy of the University of Michigan. All the material forwarded from the University of Wisconsin, about 1700 lots, will, however, be returned, with the exception of a representative series of specimens, which, with the kind permission of the University of Wisconsin authorities, will be retained.

Though this collection is by no means small, there is every reason to believe that it does not contain representatives of all the species which occur within the limits of the state. This is made apparent by examination of the check-list of the species recorded from Wisconsin, which follows at the end of this paper, and a comparison of the names incorporated in it with the accompanying lists of fishes occurring in adjoining states, which have not yet been recorded from Wisconsin. At present one hundred and forty-two species and subspecies are known from the state.

Furthermore, the territory of the state in general, with its very numerous lakes and streams, has been thus far only partially and locally covered by the field-work. The southwestern corner, a broad western strip, including the promising field of the Driftless Area, the northwestern Lake Superior drainage basin, and a large area in the north-central part, are represented as yet only by a few scattered collections. These areas will be covered

as thoroughly as possible in the next three summers, in each of which it is planned to have at least two expeditions in the field for more or less extended periods. Material from these trips, together with that which may be obtained from coöperating game wardens, high-school superintendents, and other individuals who may be interested in the Survey, should furnish enough specimens, with those already on hand, for a comprehensive study of the fish fauna of Wisconsin.

PUBLISHED WORKS ON THE ICHTHYOLOGY OF WISCONSIN

Lapham (1846), in a work on *Wisconsin: Its Geography and Topography*, published the first list of the fishes of the state.

In the years from 1870 to 1877, Hoy's interest in fishes found expression. In his work (1872 *a*) on the deep-water fauna of Lake Michigan, he mentions the discovery of two new species of whitefish, and analyzes for the first time the stomach contents of the deep-water forms. Another paper (1872 *b*) is a study of the mortality of fishes found in the Racine river. Turning to fish culture, in two papers (1876) he suggests the possibilities of fish propagation, and lists the species which he considers best suited to the various habitats to be found in Wisconsin. Finally (1877), in his catalogue of cold-blooded vertebrates, we find the second list of the fishes of Wisconsin.

Marshall and Gilbert (1905) made a study of the food and parasites of fishes from the lakes near Madison.

Marsh (1906), in a study of the plankton in Lake Winnebago and Green Lake, points out that deep lakes are not necessarily made unsuitable for fish life merely by a scarcity of plankton. Fishes feed mainly upon certain kinds of plankton (Entomostraca), and if these are moderately plentiful, as in Green Lake, a satisfactory condition for fish life results.

A paper by Juday and Wagner (1909), "Dissolved Oxygen as a Factor in the Distribution of Fishes," is another limnological study, suggesting that the abundance of plankton in a lake may act as a detriment rather than as a favorable influence on its fish fauna, in particular on its deep-water forms.

Wagner's paper (1909), "Notes on the Fish Fauna of Lake

Pepin," is interesting as furnishing a basis of comparison of the fish fauna at that time with that at later times. Another paper by Wagner (1910 *a*) demonstrates the invalidity of Agassiz's *Gasterosteus pygmaeus* as a distinct species of stickleback, showing that the great variation of the common stickleback (*Eucalia inconstans*) and the possibility of error with the equipment which Agassiz had at his command made it quite probable that the specimens he described were only examples of the wide variation of *Eucalia inconstans*. Two brief papers (1910 *a* and 1911) are descriptions of *Argyrosomus johannae* and *Leucichthys birgei*, as new species of the family Coregonidae.

Four papers by Pearse (1915, 1918, 1921 *a*, 1921 *b*) deal with the food and distribution of the fishes of certain Wisconsin lakes. The paper entitled "Distribution and Food of the Fishes in Three Wisconsin Lakes in Summer," published in 1921, may well be recommended to anglers as containing very definite information on where to fish and what bait to use. Two other papers by Pearse (1924 *a*, 1924 *b*) have to do with the parasites of Wisconsin fishes.

THE PROBLEM OF THE DISTRIBUTION OF WISCONSIN FISHES

The distribution of the fish fauna of Wisconsin as a whole, with its related problems of the geographical variation of forms, has not yet been worked out. This is a correlative problem, for which it is naturally desirable to have much material, representative of as many localities in the state as possible. It is hence advisable to wait until all the field-work to be conducted by the Survey has been done before one attempts this correlation. It is planned to map the distribution of each species as it occurs at present in the state, and to keep these maps up to date each year as the specimens are catalogued.

I have added a preliminary check-list of the species and subspecies now known to occur within the state of Wisconsin. In it I am following, in nomenclatorial and serial order, Carl L. Hubbs' check-list of the fishes of the Great Lakes and tributary waters.

SUPPLEMENTARY NOTE

As this paper is going through the press (December 15, 1926), opportunity is afforded for referring to the field-work carried on in the summer of 1926. The writer and an assistant explored the streams of the Green Bay drainage basin north of the Fox River and some adjacent streams in the Wisconsin system. Carl L. Hubbs and a party collected in some of the Lake Superior tributaries.

The lists of fishes which follow have also been brought up to date.

Check-List of the Fishes of Wisconsin

Family 1. PETROMYZONIDAE

1. *Ichthyomyzon concolor* Kirtland
2. *Entosphenus appendix* DeKay

Family 2. POLYODONTIDAE

3. *Polyodon spathula* Walbaum

Family 3. ACIPENSERIDAE

4. *Acipenser fulvescens* Rafinesque
5. *Scaphirhynchus platorhynchus* Rafinesque

Family 4. LEPISOSTEIDAE

6. *Lepisosteus osseus* Linnaeus
7. *Lepisosteus platostomus* Rafinesque

Family 5. AMIIDAE

8. *Amia calva* Linnaeus

Family 6. HIODONTIDAE

9. *Hiodon tergisus* Le Sueur
10. *Amphiodon alosoides* Rafinesque

Family 7. CLUPEIDAE

11. *Pomolobus chrysochloris* Rafinesque
12. *Dorosoma cepedianum* Le Sueur

Family 8. OSMERIDAE

13. *Osmerus mordax* Mitchill

Family 9. COREGONIDAE

14. *Leucichthys artedi* Le Sueur
15. *Leucichthys birgei* Wagner
16. *Leucichthys reighardi* Koelz
17. *Leucichthys zenithicus* Jordan and Evermann
18. *Leucichthys alpenae* Koelz

19. *Leucichthys hoyi* Gill
20. *Leucichthys johannae* Wagner
21. *Leucichthys kiyi* Koelz
22. *Leucichthys nigripinnis nigripinnis* Gill
23. *Leucichthys nigripinnis cyanopterus* Jordan and Evermann
24. *Coregonus clupeaformis* Mitchill
25. *Prosopium quadrilaterale* Richardson

Family 10. SALMONIDAE

26. *Salmo fario* Linnaeus
27. *Salmo irideus irideus* Gibbons
28. *Cristivomer namaycush namaycush* Walbaum
29. *Cristivomer namaycush siscowet* Agassiz
30. *Salvelinus fontinalis fontinalis* Mitchill

Family 11. CATOSTOMIDAE

31. *Ictiobus urus* Agassiz
32. *Ictiobus bubalus* Rafinesque
33. *Megastomatobus cyprinella* Cuvier and Valenciennes
34. *Carpiodes carpio* Rafinesque
35. *Carpiodes difformis* Cope
36. *Carpiodes cyprinus* Le Sueur
37. *Cycleptus elongatus* Le Sueur
38. *Catostomus commersonnii commersonnii* Lacépède
39. *Catostomus catostomus* Forster
40. *Hypentelium nigricans* Le Sueur
41. *Erimyzon sucetta oblongus* Mitchill
42. *Minytrema melanops* Rafinesque
43. *Moxostoma aureolum* Le Sueur
44. *Moxostoma anisurum* Rafinesque
45. *Moxostoma lesueurii* Richardson

Family 12. CYPRINIDAE

46. *Cyprinus carpio* Linnaeus
47. *Couesius plumbeus* Agassiz
48. *Nocomis biguttatus* Kirtland
49. *Erimystax dissimilis* Kirtland
50. *Erinemus storerianus* Kirtland
51. *Rhinichthys atronasus lunatus* Cope
52. *Rhinichthys cataractae* Cuvier and Valenciennes
53. *Semotilus atromaculatus atromaculatus* Mitchill
54. *Margariscus margarita nachtriebi* Cox
55. *Pfrille neogaeus* Cope
56. *Clinostomus elongatus* Girard
57. *Notropis heterodon* Cope
58. *Notropis nux richardsoni* Hubbs and Greene
59. *Notropis anogenus* Forbes
60. *Notropis heterolepis* Eigenmann and Eigenmann
61. *Notropis atrocaudalis* Evermann

61*a*. *Notropis volucellus* Cope

62. *Notropis deliciosus missuriensis* Cope
63. *Notropis deliciosus stramineus* Cope
64. *Notropis gilberti* Jordan and Meek
65. *Notropis blennius* Girard
66. *Notropis hudsonius hudsonius* Clinton
67. *Notropis hudsonius selene* Jordan
68. *Notropis whipplii whipplii* Girard
69. *Notropis atherinoides* Rafinesque
70. *Notropis rubrifrons* Cope
71. *Notropis cornutus chrysocephalus* Rafinesque
72. *Notropis cornutus frontalis* Agassiz
73. *Notropis umbratilis cyanocephalus* Copeland
74. *Phenacobius mirabilis* Girard
75. *Notemigonus crysoleucas crysoleucas* Mitchill
76. *Dionda nubila* Forbes
77. *Hybognathus nuchalis nuchalis* Agassiz
78. *Hybognathus nuchalis placitus* Girard
79. *Chrosomus erythrogaster* Rafinesque
80. *Ceratichthys vigilax* Baird and Girard
81. *Hyborhynchus notatus* Rafinesque
82. *Pimephales promelas promelas* Rafinesque
83. *Campostoma anomalum* Rafinesque

Family 13. AMEIURIDAE

84. *Ictalurus punctatus* Rafinesque
85. *Ictalurus furcatus* Le Sueur
86. *Villarius lacustris* Walbaum
87. *Ameiurus melas melas* Rafinesque
88. *Ameiurus nebulosus* Le Sueur
89. *Ameiurus natalis* Le Sueur
90. *Leptops olivaris* Rafinesque
91. *Noturus flavus* Rafinesque
92. *Schilbeodes gyrinus* Mitchill
93. *Schilbeodes exilis* Nelson

Family 14. UMBRIDAE

94. *Umbra limi* Kirtland

Family 15. ESOCIDAE

95. *Esox vermiculatus* Linnaeus
96. *Esox lucius* Linnaeus
97. *Esox masquinongy masquinongy* Mitchill
98. *Esox masquinongy immaculatus* Garrard

Family 16. ANGUILLIDAE

99. *Anguilla rostrata* Le Sueur

Family 17. CYPRINODONTIDAE

100. *Fundulus diaphanus menona* Jordan and Copeland
101. *Fundulus notatus* Rafinesque

Family 18. PERCOPSIDAE

102. *Percopsis omisco-maycus* Walbaum

Family 19. APHREDODERIDAE

103. *Aphredoderus sayanus* Gilliams

Family 20. SERRANIDAE

104. *Lepibema chrysops* Rafinesque
105. *Morone interrupta* Gill

Family 21. PERCIDAE

106. *Perca flavescens* Linnaeus
107. *Stizostedion canadense griseum* DeKay
108. *Stizostedion vitreum* Mitchill
109. *Hadropterus maculatus* Girard
110. *Hadropterus phoxocephalus* Nelson
111. *Percina caprodes caprodes* Rafinesque
112. *Percina caprodes zebra* Agassiz
113. *Imostoma shumardi* Girard
114. *Ammocrypta pellucida* Baird
115. *Boleosoma nigrum nigrum* Rafinesque
116. *Poecilichthys zonalis* Cope
117. *Poecilichthys coeruleus coeruleus* Storer
118. *Poecilichthys jessiae* Jordan and Brayton
119. *Poecilichthys exilis* Girard
120. *Catonotus flabellaris lineolatus* Agassiz
121. *Microperca punctulata* Rafinesque

Family 22. CENTRARCHIDAE

122. *Micropterus dolomieu* Lacépède
123. *Aplites salmoides* Lacépède
124. *Apomotis cyanellus* Rafinesque
125. *Allotis humilis* Girard
126. *Helioperca incisor* Cuvier and Valenciennes
127. *Xenotis megalotis peltastes* Cope
128. *Eupomotis gibbosus* Linnaeus
129. *Ambloplites rupestris* Rafinesque
130. *Pomoxis annularis* Rafinesque
131. *Pomoxis sparoides* Lacépède

Family 23. ATHERINIDAE

132. *Labidesthes sicculus* Cope

Family 24. SCIAENIDAE

133. *Aplodinotis grunniens* Rafinesque

Family 25. COTTIDAE

134. *Triglopsis thompsonii* Girard
135. *Cottus bairdii bairdii* Girard
136. *Cottus bairdii kumlieni* Hoy
137. *Cottus cognatus* Richardson
138. *Cottus ricei* Nelson

Family 26. GASTEROSTIDAE

139. *Eucalia inconstans* Kirtland
140. *Pungitius pungitius* Linnaeus

Family 27. GADIDAE

141. *Lota maculosa* Le Sueur

A considerable number of species recorded from surrounding states have not yet been collected in Wisconsin. It is probable, however, that some of these will eventually be added to the state list.

Four species which range westward into Michigan and Indiana have not been taken in Wisconsin or Illinois. These are: a lamprey, *Ichthyomyzon unicolor;* a chub, *Nocomis micropogon;* a shiner, *Notropis photogenis;* and a darter, *Cottogaster copelandi.* Furthermore, the Michigan grayling, *Thymallus tricolor,* has apparently not been secured farther west.

Native Fishes of Illinois not yet Known in Wisconsin

Following is a list of native fishes reported from Illinois, but not yet recorded on a satisfactory basis from Wisconsin. Of these, *Macrhybopsis hyostomus, Notropis boops* and *Schilbeodes miurus* have been traced northward into Minnesota, and those marked with an asterisk (*) range northward into Michigan; *Platygobio gracilis* occurs far north and far south of Wisconsin, but is a western species.

ACIPENSERIDAE

1. *Parascaphirhynchus albus* Forbes and Richardson

LEPISOSTEIDAE

2. *Lepisosteus tristoechus* Bloch and Schneider

CLUPEIDAE

3. *Alosa ohiensis* Evermann

CATOSTOMIDAE

4. * *Placopharynx carinatus* Cope

CYPRINIDAE

5. * *Opsopoeodus emiliae* Hoy
6. *Notropis phenacobius* Forbes
7. *Notropis boops* Gilbert
8. *Notropis lutrensis* Baird and Girard
9. * *Ericymba buccata* Cope
10. *Macrhybopsis hyostomus* Gilbert
11. * *Erinemus amblops* Rafinesque
12. *Platygobio gracilis* Richardson

AMEIURIDAE

13. *Ictalurus anguilla* Evermann and Kendall
14. *Schilbeodes nocturnus* Jordan and Gilbert
15. * *Schilbeodes miurus* Jordan

CYPRINODONTIDAE

16. * *Fundulus dispar* Agassiz
17. *Gambusia patruelis* Baird and Girard

AMBLYOPSIDAE

18. *Chologaster papilliferus* Forbes

PERCIDAE

19. *Hadropterus evides* Jordan and Copeland
20. *Hadropterus scierus* Swain
21. * *Etheostoma blennioides* Rafinesque
22. *Boleosoma camurum* Forbes
23. *Crystallaria asprella* Jordan
24. *Poecilichthys camurus* Cope
25. *Poecilichthys obeyensis* Kirsch
26. *Poecilichthys squamiceps* Jordan and Brayton
27. *Hololepis fusiformis* Girard

CENTRARCHIDAE

28. *Elassoma zonatum* Jordan
29. *Lepomis symmetricus* Forbes
30. *Sclerotis miniatus* Jordan
31. *Xenotis megalotis megalotis* Rafinesque
32. *Eupomotis heros* Baird and Girard
33. * *Chaenobryttus gulosus* Cuvier and Valenciennes
34. *Centrarchus macropterus* Lacépède

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THE MORPHOLOGY OF GYRINIDAE *

MELVILLE H. HATCH

THE present paper describes the chitinous skeleton of the coleopterous family Gyrinidae in terms of the accepted homologies of insect anatomy. MacGillivray's *External Insect Anatomy* (1923) has served as the basis of the work, though emendations by Crampton and others are accepted and a limited number of new terms for minor or special gyrinid structures have been introduced.

Material. — The descriptions are based on detailed dissections of the following species: *Enhydrus sulcatus* Wied., *Dineutus* (*Cyclinus*) *nigrior* Rbts., *Porrhorrhynchus landaisi* Rég., *Andogyrus seriatopunctatus* Rég., *Orectochilus* (*s. str.*) *villosus* O. Müll., *Orectogyrus specularis congoensis* Rég., *Gyretes acutangulus* Sharp, *Aulonogyrus striatus* Oliv., *Gyrinus* (*s. str.*) *spp.* The results have been checked against a less detailed dissection of *Dineutus* (*s. str.*) *grossus* Modeer, *Dineutus* (*s. str.*) *vittatus* Germ., *Dineutus* (*Cyclinus*) *discolor* Aubé, *Dineutus* (*Cyclous*) *australis* F., *Dineutus* (*Spinosodineutes*) *marginatus* Sharp, *Macrogyrus sumbawae* Rég., *Orectochilus* (*Patrus*) *crassipes* Rég., and *O. discus* Aubé. Most of the exotic material was purchased from the firm of Staudinger and Bang-Haas.

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Head and Appendages

Head capsule. — Prognathous, cocephalic. Epicranium a solid plate involving the dorsal, lateral, and latero-ventral portions of the head capsule (*e*, Figs. 1–15). Epicranial stem or coronal suture absent. Bounding the dorsal anterior portion of the epicranium is the clypofrons (*ea*, Figs. 1–15), an invagination involving the front and posterior portion of the postclypeus. Within the clypofrons the epicranial arms extend from the meson to the laterally situated pretentorina, with which the clypofrons is continuous (Figs. 17–19). The clypofrons is faintly indicated ectad in Orectogyrus. Caudad the epicranium extends to the occipital foramen, the occipital suture being completely obsolete. Ventrad it forms all but the median fifth of the surface, which is occupied by the gula (*gu*, Fig. 6).

Compound eyes. — Completely divided. Oculata (*ol*, Figs. 6, 9) or ocular sclerite not visible ectad, but consists of a shelf extending entad from the margin of the eye forming a socket. As the eye constricted, the portions of the oculata in the region of the constriction were probably brought together, and, in the completely divided eye, met to form a suture, the exoculata (*eo*, Figs. 7–15) connecting the faceted areas. In the region of the exoculata the oculata is somewhat narrower than about the margins of the faceted areas, but it is still present as an entad extending parademe. The two portions of the eye are widely separated and present more or less parallel margins to each other. The exoculata extends from the antero-ventral margin of the dorsal eye to the anterior dorsal corner of the ventral eye, which is considerably larger than the upper, though the facets composing the two are of nearly the same size (Figs. 45, 46).

Fronto-postclypeus. — Front and postclypeus fused forming a fronto-postclypeus (*po*, Figs. 1–5, 7–15). In Orectochilus it is unusually narrow. Laterad it extends onto the sides of the head as a caudally extending lobe, the clypealia (*cl*, Figs. 7–15) on whose free margin is located the precoila (*pr*, Figs. 7–15) as well as a row of bristles which are a continuation of those on the margin of the labrum and form the water-line at this point.

An unpaired membranous sclerite, the preclypeus (Stickney, 1923, p. 260) is present in the invagination between postclypeus and labrum.

Labrum (*l*, Figs. 1–15). — Primitive; anterior and lateral margins with stiff bristles of variable length which maintain the water-line in this region. The shape of the labrum varies from more transverse (Fig. 1) to less transverse or elongate in Porrhorrhynchus and certain forms of Orectochilus and Orectogyrus.

Ridges. — Frontal ridge (*fr*, Figs. 1–4, 7–15) extends from antero-dorsal corner of fronto-postclypeus to approximately anterior margin of dorsal eye. Closely associated with it is the antacaval ridge (*ar*, Figs. 7–15) defining the caudal and sometimes the dorsal margin of the antacava and anterior to and more or less parallel with the exoculata. It extends from a point near anterior margin of dorsal eye in an antero-latero-ventral direction to about dorso-anterior margin of ventral eye, where it forms an acute angle with the supraocular ridge (*sr*, Figs. 7–15), which extends caudad, closely paralleling the straight dorsal margin of the ventral eye. The head is deep set in the prothorax, the produced anterior angles of which extend forward a considerable distance along the latus of the head so that the supraocular ridge and the marganotum form a continuous margin to the dorsum of the body. At the point where it is joined by the marganotum, the supraocular ridge extends away from the margin of the ventral eye in a medio-caudo-dorsal direction closely following the anterior margin of the pronotum immediately mesad of its anterior angles, and becomes obsolete. The frontal, antacaval, and supraocular ridges form the lateral margin of the head, the peculiar direction of the antacaval ridge forming the notch that is characteristic. The frontal and antacaval ridges do not mark the water-line, which is considerably ventrad. The supraocular ridge and marganotum do mark the water-line in their region. Cauda of head completely encased in prothorax, without dorso-ventral differentiation.

In the Orectochilini except Orectochilus (*s. str.*), and best developed in Orectogyrus, there is a second or pseudofrontal

ridge (*psr*, Figs. 12, 13) paralleling the true frontal ridge, slightly dorsad and mesad to it. It extends from near the anterior angle of the fronto-clypeus to the anterior margin of the dorsal eye.

The frontal ridge is probably homologous with a similarly situated structure in Dytiscidae and perhaps other families as Hydrophilidae. In Gyrinidae it is variable in extent. It is connected with the antacaval ridge by a secondary ridge that is feebly developed in the primitive genera, but becomes distinct in the more derivative types. It fails to attain the anterior margin of the dorsal eye in Orectochilini, where it is fused with the dorsal portion of the antacaval ridge and is continuous with its caudal portion. Homologues or exact analogues of the antacaval and supraocular ridges in other Coleoptera are wanting.

Antacava. — This is a deeply excavated concavity in the epicranium (gena) ventrad to the frontal ridge and cephalad to the exoculata; posterior margin formed by antacaval ridge. The distance between the antacava and exoculata is narrowed in certain genera, due as much to the cephalad migration of the dorsal eye as to the caudad movement of the antacava. Dorsad and cephalad in the more primitive genera the antacava is bordered by an extension of the antacaval ridge. Within the antacava is the antafossa (*af*, Figs. 7–15). Antennaria not observed. The water-line across the antacava is maintained by the row of bristles on the auricular lobe of pedicel of the antenna.

Gula. — Gular stem in contact with occipital foramen, occupying approximately median fifth of venter of head. Gular bar (*gub*, Fig. 6) or pregula cephalad of gula stem and in contact along anterior margin with labium. On the median ental surface of the pregula is a small pregular parademe (*pgp*, Figs. 16, 17).

Hypostoma (Crampton, 1921, p. 74; Stickney, 1923, p. 32; *h*, Figs. 6, 27–28). — Bears a paracoila (*ptl*, Figs. 27, 28) cephalad and a postcoila (*pc*, Figs. 27) mesad; separated from epicranium (postgena) by a ridge, the crassa (*c*, Figs. 6, 27, 28) which extends from the lateral apex of the pregula in a deep curve close to the margin of the eye to a point just laterad of the postcoila.

Cervix. — Cervacoria (*cc*, Figs. 6, 19) attached to head along margin of occipital foramen. Cervical sclerites reduced to a

single minute cervepisternum (*ccs*, Fig. 6) in the cervix just laterad to the point of union of the gular suture with the margin of the occipital foramen.

Tentorium and parademes of head. — Caudal margin of gula produced entad to form a gular parademe (*gp*, Fig. 19). Caudad the entire margin of the epicranium where it borders upon the occipital foramen is produced entad to form an occipital parademe (*ocp*, Fig. 19) which is continuous with the metatentoria (*mt*, Figs. 17–19). The dorsal margin of the occipital parademe in Dineutus is produced to form a pair of lobes, the tendons of the extensors of the head (*tex*, Fig. 19).

Metatentoria (*mt*. Figs. 17–19) continuous with right and left portions respectively of occipital parademe, and invaginate along entire line of gular suture from occipital foramen to submentum. About the level of the juncture of the gular stem with the pregula each metatentorium gives rise to a broad mesad extending lobe, the laminitentorium (*lt*. Figs. 17, 18), which does not fuse with its fellow along the meson. Immediately cephalad of the laminitentorium, each metatentorium gives rise to a latero-dorso-cephalad extending arm, the pretentorium (*pnt*, Figs. 17, 18), which invaginates on the latus of the head just anterior to the antacava and is continuous with the lamella of the clypofrons. No supratentorium was found, though Stickney (1923, Fig. 452) shows one for Dineutus extending from the pretentorium near its juncture with the metatentorium. Near the occipital foramen the metatentorium gives rise to another mesad extending lobe which may be termed the metatentorial lobe (*mtnl*, Figs. 17, 18). In Aulonogyrus a second elongate mesad extending process immediately anterior to the metatentorial lobe was detected.

Corpotentorium present only in Enhydrini (*ct*, Fig. 17). It arises on either side from the lateral surface of the metatentorium as a pair of extremely attenuated strands, which extend caudad about half-way to the occipital foramen, turn mesad at right angles, and fuse along the meson, from which point it extends cephalad to between the laminitentoria.

Antenna (Figs. 20–26). — Attached to head capsule at bot-

tom of deep antacava. Scape (*sc*) large, cup-shaped, constricted proximad and then slightly expanded to form a small bulbus (*b*) to which is attached the antacoria. Pedicel (*p*) attached at bottom of cup-shaped scape, expanded dorso-cephalad in a large auricular lobe (*al*) bearing along its margin a row of bristles which form the water-line across the antacava. Flagellum (*f*) connected with unexpanded portion of pedicel by a membrane, the flagellacoria (*fc*, Figs. 20, 21, 25), and consists of six to nine closely united segments, as follows: ENHYDRINI, 9–6 segments: *Enhydrus sulcatus* Wied., 6 segments; Dineutus, 6 segments (*grossus* Modeer and *vittatus* Germ. of Dineutus [*s. str.*], *americanus* Say [MacGillivray, 1923, p. 88], *nigrior* Rbts. and *discolor* Aubé of subgenus Cyclinus, *australis* F. of subgenus Cyclous, *marginatus* Sharp of subgenus Spinosodineutes), *Porrhorrhynchus landaisi* Rég., 8 segments with last two sutures quite indistinct; Andogyrus, 9 segments, the last somewhat modified (*buqueti* Aubé [Régimbart, 1907, Figs. 4, 5] and *seriatipunctatus* Rég.); *Macrogyrus sumbawae* Rég., 8 segments with the last suture somewhat indistinct. — ORECTOCHILINI, 9–6 segments: *Orectochilus villosus* O. Müll., 9 segments, *Orectocyrus specularis congoensis* Rég., 6 segments, *Gyretes acutangulus* Sharp, 9 segments. — GYRININI, 7 segments: *Aulonogyrus striatus* Oliv., *Gyrinus sp.*

The segments of the flagellum are closely united to form a compact club that apparently functions as a unit. The basal segments are more distinct than the distal. Close observation and frequently extended treatment with KOH solution are necessary to reveal the sutures. Since the great majority of Coleoptera, including Carabidae and Dytiscidae, have nine-segmented flagella, it is probable that this is the primitive number in Gyrinidae and modification has involved reduction, though a secondary increase is not unthinkable. Reduction has apparently involved fusion of terminal segments in Enhydrini and Gyrinini. In the six-segmented Orectogyrus (Fig. 25) some of the intermediate segments appear likewise to have been involved, so that the two conditions are not homologous. The antenna of Dryops (Dryopidae) is only superficially similar to that of Gyrinidae and no homology is to be traced (Fig. 58).

Mandible (Figs. 17–30).—The mandible has the general shape of a three- or four-sided pyramid, of which the base represents the caudal surface (*cs*), one side the ventral surface (*vs*), another side the median surface (*ms*), a third side the lateral surface or scrobe (*scr*), and the fourth side the dorsal surface (*ds*). The scrobe is a dorso-ventrad concave surface extending from the base of the mandible between the preartis and postartis cephalad and mesad in a broad curve. Its two apical angles are acutely produced to form the more apical dorsal distadentis (*dd*) and the ventral distadentis (*vd*). The scrobe intersects at an obtuse angle the dorsal surface, which is slightly concave and bounded cephalad and laterad by the scrobe's dorsal margin. Mesad the dorsal surface intersects the median surface and caudad it intersects the base at about a right angle. Laterad on the caudal margin of the dorsal surface is the preartis (*pa*). Cephalad and laterad the ventral surface intersects the scrobe along the curved ventral margin of the latter at slightly less than a right angle, mesad it intersects the median surface and caudad it intersects the base at about a right angle, laterad on its caudal margin is the postartis (*ptc*). The ventro-medial margin of the mandible is produced at about a 105-degree angle to form a proxadentis (*pd*). The mesal surface is concave and intersects the scrobe cephalad, the ventral surface ventrad, the dorsal surface dorsad, and the base caudad. In Porrhorrhynchus a ridge extends obliquely from the apex of the dorsal distadentis to the point of juncture of the mesal surface with the ventral surface and base. The mandible articulates with the head-capsule by means of the precoila on the clypealia and the postcoila (*ptl*) on the hypostoma. It is flexed by the large rectotendon (*rt*) attached to the proximal portion of the ventro-mesal margin and relaxed by the small extensotendon (*et*) attached to the ventro-lateral margin.

The apical portion of the ventral surface in most of the genera except Porrhorrhynchus is crossed by a fine line or furrow (*fur*), usually more extended on the dextral than on the sinistral mandible, except in Gyrinini, where it is subequally extensive on both. It is perhaps a device to help the mandibles interlock.

At rest the apex of the dextral mandible is dorsad to the apex of the sinistral one. The sinistral dorsal distadentis is truncate or slightly bifurcate; the dextral one is simple. Prolonged soaking in potassium hydroxide solution shows that the apical portions of the mandible, including the teeth, are more heavily chitinized than the proximal portions, shown by stippling in Figure 29.

In the Orectochilini (Fig. 30) the lobe that marks the proximal portion of the medio-ventral margin at the point of insertion of the rectotendon is more or less effaced.

Maxilla (Figs. 31–33). — Cardo (*ca*) with preartis (*par*) along proximal margin, which articulates against paracoila located on proximal portion of mesal margin of hypostoma; mesal margin of cardo produced to form cardoprocess (*cp*), "to which muscles are attached by means of the cardotendons" (Crampton, 1923, p. 83). Cardo articulates distad with basistipes (*bs*), which is in contact in ventral aspect with the subgaleo-lacinia (*sgla*) along its entire meso-distal margin. Dorsad the basistipes is only about half as extensive as it is ventrad and articulates distad with the palpifer (*mpf*), which appears only in dorsal aspect and laterad bears the four-segmented palpus (*mp*), the distal segment of which is as long as the basal three together. Distad the palpifer is in contact with the subgaleo-lacinia, which comprises the fused distal lacinia (*la*) and basal subgalea (*sg*) (mediostipes, Crampton, 1923, p. 105), and whose distal portion only is visible in ventral aspect. Caudal margin of subgaleo-lacinia with deep-rounded emargination, the point of attachment of the stipital plica (*sp;* Crampton, 1921, p. 104, Fig. 4). Apex of subgaleo-lacinia acute. Mesal margin with lacinirastra (*lac*) divided into a distal and proximal portion, the latter borne on margin of a lobe (not prominent in Gyrinini, slightly prominent in Enhydrus, anterior angle produced and acute except in Enhydrus and Porrhorrhynchus, margin distinctly emarginate in Porrhorrhynchus), which is the product of dorsal portion of mesal margin of subgaleo-lacinia. In the Gyrinini the extreme distal portion of the basistipes articulates with the galea (*gl*, Fig. 32) (absent in Enhydrini and Orectochilini), a long narrow-curved acutely-pointed piece, the fused basigalea and distagalia of Carabidae,

that at rest lies along the latero-cephalic margin of the lacinia, but terminates slightly before it.

The labacoria connects the mesal or caudal margins of the ventral aspect of the cardo and subgalea with the dorsal surface of the submentum. The maxacoria (*mc*, Fig. 33) connects the mesal or caudal margin of the dorsal aspect of the cardo, basistipes, palpifer, and lacinia with the margin of the hypostoma in the region of the postcoila.

Labium (Fig. 34). — Attached to head-capsule along cephalic margin of pregula, forming the intervening mentasuture (*mts*). Submentum (*sm*) expanded laterad to form lateral lobes (*ll*), between which are the completely fused stipulae (*st*) separated from submentum by a suture. Mentum absent or fused with stipulae. Caudal margin of stipulae usually somewhat emarginate or bisinuate, apical margin with row of short setae. Towards the proximal angles of the stipulae are the palpifers (*lpf*), only slightly larger than proximal segments of the three-segmented labial palpi, which they bear and whose terminal segment is larger than the two basal ones combined. Paraglossae and glossae absent.

Pharynx (Figs. 35, 36). — Propharynx entirely membranous. Epipharynx (*ex*) attached to venter of labrum, consists of pair of quadrate or subquadrate sacks that are in contact or nearly so along meson. The epigustra (*eg*) is the portion of the propharynx caudad to the epipharynx.

The hypopharynx (*hx*) constitutes the anterior portion of the prepharynx and is attached to the dorsum of the submentum and stipulae. It is somewhat trilobate along its cephalic margin, consisting of two quite prominent lateral lobes and a single less prominent median lobe. MacGillivray (1923, p. 131) notices a similar condition in certain Exopteraria and proposed a terminology for it, but the two sets of conditions are evidently not homologous. The subgusta (*su*) is the portion of the prepharynx caudad to the hypopharynx.

Pharyngeal sclerites of prepharynx largely fused or wanting; saliviae (*sl*), however, well developed, extending slightly along the postero-lateral margins of the hypopharynx and along its

caudal margin fusing in the middle. From the saliviae at either posterior corner of the hypopharynx a slender chitinous arm (*fh*) extends caudo-dorsad to the propharynx, reinforcing the pharyngeal wall and marking practically the cephalic limits of epigusta and subgusta. The arms do not extend onto the propharynx, but continue in a caudo-dorsal direction away from the pharyngeal wall, forming large tendons. The structure seems to be homologous to the fulcrum hypopharyngeum of Scarabaeidae (Hardenberg, 1907; Hayes, 1922), and probably represents the fusion of some of the pharyngeal sclerites with the salivia. The tendons may be linguatendons (MacGillivray, 1923, p. 131), in which case the linguacuta to which the linguatendons are attached is involved. The lingua is the sclerite that MacGillivray figures lying between the linguacuta and the salivia and may be another sclerite represented. If this is the case, the pharyngea and paralingua have been lost.

Thorax and Appendages

Prothorax (Figs. 37–39). — Notum, a single plate consisting of a dorsal epinotum extending onto the lateral margins of the venter as the pleuranotum (*pln*), from which it is separated by the marganotum. Epinotum unmodified except in Gyrinus, where it is marked by a distinctly impressed and frequently punctate line along lateral portions of anterior margin as well as by one or two less distinctly impressed transverse lines on disc. The pronotasuture (*prns*, Figs. 37–39) separates the pleuranotum from the proepimeron (*pepi*).

Prosternum (sternannum, *pstn*) and proepisternum (*pest*) fused, together occupying entire cephalic and median portions of venter of prothorax. Procoxacavae (*pcc*) large, situated on either side of meson somewhat caudad of anterior margin of prosternum, so that there persists between the anterior margin of the coxacava and the anterior margin of the prosternum a transverse area of the prosternum that is not involved in the coxacavae nor covered by the coxae when at rest. This transverse area, except in a few generalized species of Orectochilus (*s. str.*), is extremely attenuated in Orectochilini, correlated with which

is the marked widening of the undepressed area posterior to coxacavae. Between the coxacavae there extends from the anterior undepressed portion of the prosternum in Enhydrini and Gyrinini a distinct coxal process (*pcxp*), reduced to an acute angulation in Orectochilini. Posterior to the coxal process the coxae are in contact when at rest and the coxacavae are separated by a feeble ridge. Coxacavae limited caudad by feeble ridge, posterior to which the prosternum is reflexed slightly dorsad and, on the cauda of the prothorax, is produced laterad as a pair of narrow arms dorsad to the proepimera and extending to the ental surface of the epinotum. Mesocoria (*msc*) attached to caudal margin of mesal portion of prosternum and to dorso-median margin of lateral arms. Immediately caudad and entad to attachment of mesocoria, the mesal margin of the prosternum gives rise to a pair of profurcae (*pfrc*), one on either side of meson, which extend slightly cephalad and markedly caudad protruding from the posterior foramen of the prothorax. The profurcina (*pfri*) determines the caudad extension of the sternannum or anterior portion of the primitive sternum. The sternellum is, accordingly, absent or fused with the mesocoria (cf. MacGillivray, 1923, pp. 155, 157).

Coxafossae (*pcxf*) located in extreme lateral portions of coxacavae, somewhat obscured laterally by protruding portions of proepisternum and proepimeron. Propleural suture (*ppls*) extends from latero-cephalic margin of coxafossa in a cephalo-lateral direction to the notasuture, which it joins slightly posterior to its anterior termination at cephalic margin of prothorax. Caudad the proepimeron (*pepi*) is produced in a wide lobe over an appreciable portion of mesothorax. On the cauda of the prothorax the proepimeron extends dorsad to the prosternum.

Procoria attached to ental surfaces of prothorax somewhat caudad to its anterior margins, which form a socket for reception of the cauda of the head.

Meso- and metathorax (Figs. 40–44, 47).—Meso- and metathorax firmly united. Pro- and mesothorax connected by mesocoria, which is membranous and of sufficient extent to allow for some slight motion of prothorax. Prothorax overlaps meso-

thorax except in midventral region, where the mesosternum is produced in a distinct lobe, overlapping the prosternum and extending slightly between the front coxae to form the caudal wall of the procoxacavae. The caudal margin of the epinotum overlaps the metatergum and the bases of the elytra. Mesad it is sometimes produced as a feeble lobe which obscures the entire scutellum in Dineutus, Porrhorrhynchus and Gyretes. Ventrad the caudal margins of the proepimera are produced and cover portions of the mesoepisterna and form the anterior margins of the profemacavae or grooves for the reception of the profemurs.

Mesospiracles (*mss*, Fig. 37). — Situated laterad on ventral surface of mesocoria close to its attachment to prosternum, oval, apparently open, and surrounded by a distinct peritreme.

Mesosternum. — Mesosternum (mesosternannum, *msstn*, Figs. 40–44, 49) and mesoepisternum (*msest*) fused. The lateral portions of the mesal region are, however, sharply defined by a profemacaval ridge (*pfr*) forming the meso-posterior margin of the caudo-laterally extending profemacava (*pfc*). This ridge extends latero-caudad past the mesosternum across the mesoepimeron (mesosternepimeron) and the anterior portion of the metaepisternum (metasternepisternum) onto the hypomera where it bends forward in a curve. The anterior margin of the profemacava is formed by a portion of the hypomera and the caudal lobe of the proepimeron. Accordingly, there is a mesally situated diamond-shaped area bounded latero-cephalad by the profemacavae and latero-caudad by the mesocoxae and usually termed the sternum, the regions immediately latero-cephalad being termed the episterna. The profemacaval ridge is without a suture or a lamella; whether or not it is homologous in position with the mesosternasuture the present study does not reveal. The profemacava is in part an adaptation to aquatic conditions, a device to get the anterior legs out of the way when the animal is swimming. In the present discussion the terms mesosternum and mesoepisternum are retained only as regional names. The sharp ridge bounding the anterior lobe of the mesosternum is a continuation of the union of the femacaval with the mesoepisternal (*r*, Fig. 49) ridge. From the margin of the anterior

lobe the mesosternum extends dorsad and slightly caudad to the line of attachment of the mesocoria.

The posterior portion of the middle line of the mesosternum is traversed by the mesosternal suture (*msts*, Figs. 40–44), marked entad by the mesosternal lamella (*mssl*, Fig. 47). The mesosternum, instead of being small and crowded almost out of sight between the prosternum and metasternum as in Dytiscidae, etc., is large. It is possible to think that this enlargement took place phylogenetically by the extension caudad of the lateral margins of the ancestral mesosternum, and that the pair of lobes thus produced met along the meson and formed the mesosternal suture, a unique gyrinid structure.

The latero-caudal margins of the mesosternum form the medio-anterior margins of the mesocoxacavae (*mscc*, Figs. 40, 41), along which are the mesocoxafossae (*mscf*). Entad to the line of attachment of the mesocoxacoria the margin of the mesosternum is produced in a narrow lamella which is continuous with the mesosternal lamella and on either side of the meson is produced to form a cephalad-extending mesofurca (*msf*, Fig. 47). The distal portions of the mesofurcae are expanded as discs which serve as points of attachment for muscles. Mesosternellum completely obsolete.

Mesopleuron. — A mesoepisternal ridge (*r*) extends across the mesoepisternum from the anterior lobe of the mesosternum to the mesoepimeron and forms the lateral portion of the anterior margin of the venter of the mesothorax. It divides the mesoepisternum into a ventral mesosternepisternum (*mssn*, Fig. 49) and a cephalic mesonotepisternum (*msss*), which may be so named, even though not separated by an episternal suture (which MacGillivray, 1923, p. 178, indicates as secondary) and not certainly homologous with these parts in other insects. The mesoepisternum is undivided in Harpalus and Phyllophaga. At the attachment of the mesocoria there is nothing to divide sternum from episternum. Entad to the attachment of the mesocoria, the mesosternum and mesoepisternum are produced somewhat to form a mesoepisternal parademe.

The mesoepimeron (*msepi*, Figs. 40–44, 47, 49) is a narrow

sclerite on the latero-caudal margin of the mesoepisternum extending from the mesocoxacava to the mesopleuralifera or mesopleural wing process (*mswp*, Fig. 49) and separated from it by the mesopleural suture (*mspls*). An extension of the mesoepisternal ridge, the mesoepimeral ridge (*msepr*), divides it into a ventral mesosternepimeron (*msps*), and a cephalo-lateral mesonotepimeron (*mspn*). The latter is narrow and practically all involved in the invaginated mesoentopleuron (*msn*), an apodeme that extends the entire length of the mesopleural suture.

Mesoparaptera represented by small mesopreparapteron (*mspp*) or mesoprealifera in the pleurotaxis just meso-cephalad of the mesopleuralifera.

Portions of the mesoepisternal and mesoepimeral ridges as well as portions of the lateral margin of the mesosternepimeron, a continuation of the mesoepimeral ridge, are frequently produced to form one or two lobes, which apparently fit into portions of the anterior hypomera of the elytra and seem to be of some service in holding the elytra in place, especially in Gyretes (Figs. 78, 79).

Metasternum (*mstn*, Figs. 40–44, 47). — Situated between mesosternum and mesocoxafossae in front and metacoxae behind. Separated from metaepisterna by metasternasutures (*msr*), which are invaginated to form metasternal lamellae (*msrl*, Fig. 47). The adjacent margins of the metasternum and metacoxae are invaginated to form a metasterno-metacoxal lamella (*mml*).

Mesocoxae (*mscx*). — The mesocoxae possess a very slight power of movement, intermediate between the highly mobile procoxae and the immovable metacoxae which form integral portions of the ventral surface and are not at all elevated above it. In Orectochilini the process of fusion of the mesocoxae with the mesosternum has proceeded further than elsewhere. The mesocoxae are widely separated (primitive) in Enhydrus, Andogyrus and Macrogyrus, narrowly separated in Dineutus, Porrhorrhynchus, Orectochilus, Gyretes and the Gyrinini, approximate in most of the species of Orectogyrus.

The following structures (Crampton, 1923, p. 126) are noted for the mesocoxae without making any assumptions concerning

their homodynamy with similar structures in the metacoxae. Along the extreme caudal margin is the mesotrochacoila, involving a cavity, the mesocoxatheca, and a process on either side, the lateral (anterior) and median (posterior) mesotrochantifers, the latter of which is enlarged and produced caudad somewhat to form a mesocoxal process (*mscp*, Figs. 42, 43), a projection caudad over the base of the trochanter of the much flattened mesocoxacrista (*msci*) or ridge which occupies the entire mesal portion of the coxa. This ridge has a more or less definite margin, the mesocoxacarina (*mscr*, Figs. 40–44) or mesofemacaval ridge, which becomes less distinct cephalad and extends onto the lateral portion of the mesosternum. Laterad to the ridge is a slight depression for the reception of the mesofemora (the mesofemacava, *msfc*, Figs. 40–42, 44). That portion of the ridge on the mesocoxa may likewise be termed the mesocoxasulcus (*mscsl*, Figs. 42, 43), after MacGillivray.

The mesocoxa occupies the mesocoxacava (*mscc*, Figs. 40–41). No trochantin was found. Cephalo-laterad the mesocoxa bears a distinct lobe, the mesocoxartis. The mesocoxafossa is elongate and located along the meso-cephalic margin of the mesocoxacava, providing an uninterrupted opening for the extension of muscles between the mesocoxa and mesosternum. Whereas in Dytiscidae the mesopods are prehensile and do not require large muscles for their operation, so that the mesosternum is small; in Gyrinidae the mesopods are used in swimming almost as much as the metapods and require large muscles for their operation. Such muscles are provided for in the combined mesosternum-mesocoxa, and this, while a good deal less than equal to the combined metasternum-metacoxa, is very much larger than in Dytiscidae.

The mesocoxafossa occupies only a small portion of the floor of the mesocoxacava, most of which consists of metasternum (*mstn*). It is the great extension caudad of the mesocoxacava, attaining almost to the metacoxa, that gives the exposed portions of the metasternum the shape that is characteristic, the exposed median portion, the mid-lateral narrowings, and the lateral "wings." The metasternum really extends as a broad plate across the venter of the body from one episternum to the other.

Metacoxae (*mcx*, Figs. 40–44). — Consist of large immovable triangular plates constituting integral parts of the venter, and adjacent along entire mesal margin, forming an intermetacoxal suture (*ims*), which invaginates to form an intermetacoxal lamella (*iml*, Fig. 47). A portion of the anterior end of this lamella is to be regarded as an infolded portion of the metasternum, for slightly posterior to the point of junction of the intermetacoxal lamella with the metasterno-metacoxal lamella arises the single cephalad-projecting metafurca (*mf*), which marks the caudal extension of the sternannum. Metasternellum absent or fused with intermetacoxal lamella posterior to point of origin of metafurca. The metafurca is the result of the fusion of the pair of metafurcae of generalized forms. Evidence of its dual origin is in the bifurcate condition of its distal portion, for about the level of the caudal margin of the mesosternum the metafurca is produced in a pair of arms which are expanded distad, providing places of attachment for muscles. The bifurcated arms are fused distad in Aulonogyrus (Fig. 48).

The oblique latero-caudal margins of the metacoxae are broadly reduplicated (*mcxr*, Fig. 47), the reduplication being continuous with the intermetacoxal lamella. Mesad there is a further secondary reduplication. Neither of these reduplications constitutes a portion of the endoskeleton, being exterior to the line of attachment of the duacoria. Just laterad to the lateral termination of the secondary reduplication, the margin of the metacoxa gives rise to a cephalad-extending long slender furcoid metacoxal parademe (*mcxp*) that attains approximately to the level of the anterior margin of the mesocoxa. Its distal portion is expanded for the attachment of muscles. Laterad the metacoxa is in contact with the metaepisternum. Entad along the line of their contact is produced a metacoxo-metaepisternal lamella (*mpl*) that is continuous caudad with the metacoxal reduplication and cephalad with the metasterno-metacoxal lamella and the metasternasutural lamella. The portion of the basal abdominal segments that is depressed for the reception of the metacoxa constitutes a metacoxacava, the larger portion of which, however, is involved in the metacoxafossa.

The metatrochacoila is hidden beneath the strongly projecting metacoxal process (*mcp*, Figs. 40–43), the continuation of the metacoxacrista (*mcs*). This is bordered by the metacoxacarina (*mcr*), which is pronounced caudad but becomes less distinct as it extends in a broad curve towards the metaepisternum. Caudo-laterad to the metacoxacarina is the metacoxasulcus (*mcsl*). Laterad the ventral surface of the metacoxa is defined by a ridge, dorsad to which the coxa extends forming a small quadrangular plate, the latacoxa (*lc*, Fig. 50), which is continuous cephalad with the lateral aspect of the metapleuron and caudad with the latasternites.

The relative area of the metacoxacrista and the metacoxasulcus varies as do the cephalic extension of the lateral portions of the metacoxa and the size of the metasternal "wings." In Enhydrini the anterior margins of the metacoxae are very slightly oblique; the area of the metacoxasulcus is less than that of the metacoxacrista. The remaining groups are characterized by the cephalic thrust of the lateral portions of the metacoxae, resulting in extremely oblique anterior metacoxal margins and a great reduction in the size of the metasternal "wings." Apparently correlated with this is a narrowing of the metacoxacrista and a corresponding broadening of the metacoxasulcus, so that the latter is larger than the former, reaching an extreme in certain species of Orectochilus. This entire group of changes is probably evidence of increased adaptation to the aquatic environment. It involves an antero-posterior compression of the sclerites, and, in Orectochilini, an increased narrowing of the body. The increase in breadth of the metacoxasulcus enables a greater and more complete retraction of the metalegs.

Metapleuron (Fig. 50). — Metapleuron composed of a ventral metasternepisternum (*mess*) and a lateral metanotepisternum (*mesn*) separated by the metaepisternal ridge (*mer*), that marks the lateral margin of the venter in this region. The metasternepisternum extends along the lateral margin of the venter from the mesosternepimeron along the metasternum to the metacoxa. The metanotepisternum is elongate and situated on the latus of the body between the metaepisternal ridge ventrad and the

metapleural suture (*mps*) dorsad. This suture is invaginated slightly throughout its length to form a lamelloid metaentopleuron.

Metaepimeron (*mepi*) confined to latus of body dorsad to metapleural suture, consists of a narrow plate not well developed and often apparently involved to a considerable extent in the metaentopleural invagination. Posteriorly its dorsal margin is produced as an elongate oval disc, the supraepimeron (*se*). The metapleural suture extends from the latacoxa in a dorso-cephalic direction to the metapleuralifera or metapleural wing process (*mwp*) at the dorsal end of the anterior margin of the metapleuron. Anterior to the metapleuralifera and in the pleurotaxis is the metapreparapteron (*mpp*) or metaprealifera, an elongate irregular sclerite.

Metaspiracles. — The second pair of spiracles are in the metacoria connecting the mesoepimeron with the metaepimotepisternum. They are apparently open and surrounded by a peritreme.

Legs (Figs. 51–57). — Legs specialized entirely through modification of parts and not through loss or fusion. Each leg with coxa (*cx*), trochanter (*tr*), femur (*fe*), tibia (*t*) and a five-segmented tarsus (*ta1-ta5*) bearing an articularis with a pair of curved claws (*cw*) which are situated latero-mesad (transverse) and not cephalo-caudad. Mesopods and metapods strongly natatorial. Propods largely raptorial or prehensile. The tarsal segments of all the legs are alike in one very anomalous respect; they are depressed laterally rather than dorso-ventrally. Trochantin absent except in propods (*tn*, Figs. 51, 53), where it is closely associated with the head of the coxa in the procoxacoria.

Propods (Figs. 51–53). — Procoxa movable, subglobular, and so deeply buried in the coxacava that its distal surface protrudes only very slightly above the general ventral surface of the prothorax. It extends mesad from its point of attachment (coxacoila) near the lateral margin of the procoxacava. Articulated to its distal end, the protrochoila, is the triangular protrochanter. Coxatrochliae small. Femasuture (*fs*) or suture along which the femur and trochanter articulate slightly movable.

Fematrochliae small. A small subquadrate sclerite located ventrad in the tibiacoria and closely associated with it is the patella. The distal portion of the venter of the femur is excavated somewhat for the reception of the tibia at rest in a distinct femasulcus. To effect such an articulation the proximal portion of the tibia is somewhat bent to form the tibiaflexis (*tf*).

The femur freqently bears important specific and secondary sexual characters. In certain Dineutus its distal angle is more or less produced and acute in the male, rounded in the female. In other Dineutus males its ventral margin bears a distinct tooth which is absent in the female. The number of setigerous punctures on the lateral aspect of the femur is said to be a character of value in separating certain species, but it is quite variable.

There are five protarsomeres or tarsal segments. The three intermediate ones are subequal. The basitarsus or proximal tarsomere is often slightly longer than any of the intermediate ones and the distal tarsomere is the longest of the five. Protarsomeres not distinctly compressed but subcylindrical in female (Fig. 51), expanded and laterally compressed in male (Fig. 53), and bear on their mesal aspect a dense brush of bristles, used in clinging to the dorsal surface of the female during copulation and a widespread secondary sexual character in Coleoptera. Male protarsomeres most strongly expanded in Enhydrus. The distal protarsomere bears an articularis concealed within its distal end bearing a pair of curved protruding claws.

Meso- and metapods (Figs. 54–57). — The meso- and metacoxa have been described above. They are largely immovable, and their function is, together with the meso- and metasternum, to contain the muscles for the operation of the swimming legs. The remaining portions of the meso- (Figs. 54, 56) and metapods (Figs. 55, 57) similar except for relatively smaller mesotibia and the smaller intermediate mesotarsomeres. Throughout they are strongly expanded and laterally compressed, and bear along their more distal margins dense rows of stiff bristles which further increase their efficiency as powerful paddles. At rest the parts fold so that the more distal piece lies on the lateral surface of the

more proximal piece. The metapod is probably slightly more efficient than the mesopod.

The meso- and metatrochanters articulate with the coxae by means of large and well-developed trochartes. Their distal portions are large laterally compressed lobes that articulate along their dorsal margins, the femasuture (*fs*), with the equally compressed femurs. Tibiacoila (*tcl*, Fig. 54) at dorsal end of distal margin of meso- and metafemurs, articulating with the tibiartis (*tar*) at dorsal end of the proximal margin of the meso- and metatibia, which are laterally compressed and somewhat wider distad than proximad. They bear along all but their proximal margins a row of stiff bristles. Tarsacoila (*tac*, Figs. 54, 56) located at ventral extreme of distal margin of tibia.

The basitarsus or unatarsomere (*ta1*, Figs. 54–57) is triangular and nearly equal in size to the four distal tarsomeres together. It articulates by a unatarsartis (*ta1a*) at the dorsal extreme of its proximal margin. When expanded its distal margin lies along and probably slightly overlaps the distal margin of the tibia. Its dorsal margin is free and bears a row of short stiff bristles. Its distal margin constitutes the third side of the triangle and overlaps the proximal margin of the second or duatarsomere (*ta2*). The articulation of the una- and duatarsomeres is near the angle of the proximal and distal margins of the unatarsomere on the distal margin (duatarsacoila, *ta2c*) and on the ventral portion of the proximal margin of the duatarsomere (duatarsartis, *ta2a*). The duatarsomere is dorso-ventrad elongated — not transverse, latero-mediad (MacGillivray, 1923, p. 265), — lying between and overlapping the unatarsomere and the tretarsomere (*ta3*), which latter closely resembles the duatarsomere in shape and articulation (*ta3c*, *ta3a*). Their dorsal margins both bear a row of short stiff bristles.

The quatarsomere (*ta4*) is likewise dorso-ventrad elongated and lies along and overlaps along its proximal margin the distal margin of the tretarsomere. The quatarsacoila (*ta4c*) and the quatarsartis (*ta4a*) are located towards the ventral extremity of the distal margin of the tretarsomere and the proximal margin of the quatarsomere respectively. Because of the position of the

quitarsomere, the ventral margin and ventral portions of the distal margin of the quatarsomere are free. The small subquadrate quitarsomere (*ta5*) is located in the extreme dorso-distal angle of the quatarsomere and is separated from it by a suture in place of an articulation, which is obsolete in Aulonogyrus (Figs. 56, 57). The free dorsal margins of the qua- and quitarsomeres bear a row of short stiff bristles, and their free distal margins numerous long bristles. The intermediate metatarsomeres are subequal in size; the second and third mesotarsomeres are much smaller than the mesoquatarsomere. The quitarsomere bears an articularis with a pair of curved claws. At rest the tarsomeres, except the quitarsomere, are folded back on each other like a fan, and the whole tarsus is folded back on the tibia.

Mesonotum (Figs. 59–69). — The smaller size of the mesonotum over the metanotum is correlated with the fact that the mesonotum contains only muscles to operate the elytra, whereas the metanotum must contain the muscles for operating the wings in flight. The mesonotum consists of an anterior mesopraescutum (*mspc,* Figs. 60, 63–65, 68, 69), an intermediate mesoscutum (*mst,* Figs. 59–69), and a posterior mesoscutellum. Postscutellum absent.

Mesopraescutum. — The anterior margin of the mesonotum constitutes the mesopraescutum. To it is attached the mesocoria, entad to which (*lm,* Figs. 60, 63–65, 68, 69) is an extensive mesally situated phragma (a parademe), the mesoprephragma (*msph*). In Gyrinini (Fig. 69) the mesoprephragma is produced in a pair of long arms. In Enhydrus (Fig. 63) it is a simple lobe (primitive). In the remaining enhydrin genera (Fig. 60) it is bilobed. In Orectochilus (Fig. 68) it consists of a pair of lobes separated by more than their own width. In Orectogyrus (Fig. 65) the lobe is wide and simple. In Gyretes it is produced in a single elongate much narrowed lobe.

Mesoscutum (Figs. 59–69). — There is some question as to the exact interpretation to be placed on the general area of the mesonotum cephalad to the mesoscutellum. It is divided bilaterally by a medial suture extending from its anterior margin to the mesoscutellum and forming a distinct lamella entad.

Either half is further divided, except in Porrhorrhynchus (Fig. 60), into an anterior and posterior portion by a ridge extending in a curve from about the anterior corner of the mesoscutulis to or near the lateral margin of the mesonotum. In Orectochilini (Figs. 66, 67) compression has forced all portions of the mesonotum cephalad of the mesoscutulis over onto the cephalic aspect of the mesonotum. The posterior portion of the lateral margin of the anterior of these two divisions into which the lateral region of the mesonotum is divided bears a distinct medalaria (*msm*, Figs. 59, 66) or anterior notal wing-process. The lateral margin of the posterior of these two divisions is very slightly lobed, which may, perhaps, be interpreted as a caudalaria (*mscd*) or posterior notal wing-process, but nothing is present to correspond with the extensive caudalaria shown by Snodgrass (1909, Fig. 128, Plate 55) for Dytiscus.

According to Snodgrass (*ibid.*) the anterior pair of the two divisions bearing the medalariae is the mesopraescutum. The posterior pair, completely separated from each other by the mesoscutellum, and without or with doubtful caudalaria is the divided mesoscutum. Snodgrass apparently overlooked the medial suture on the mesopraescutum in his figure of *Dytiscus dauricus* Gebl., though I found it in *Dytiscus harrisii* Kby. Nowhere is the praescutum mentioned as being divided, whereas a divided scutum is a common coleopterous characteristic. Thus doubt is cast on Snodgrass's homologies.

MacGillivray (1923, pp. 193–199) intimates that the praescutum tends to become reduced in specialized insects. Crampton (1909, p. 12) limits the mesopraescutum at times to the phragma. MacGillivray (1923, p. 196) considers both medalaria and caudalaria to be situated on the scutum, which assigns the entire area under discussion to the scutum, the view held by Euscher (1910, pp. 21–23) for *Dytiscus marginalis*, but not the view held by Van Zwaluwenburg (1922, p. 18) for an elaterid.

The significance of the transverse ridge and the anterior and posterior portions of the mesoscutum remains to be determined. The mesal suture may be the result of the drawing together of the parapsides described (1923, p. 197) and figured (p. 156) by

MacGillivray, so that the lamella would involve the prenota and the lateral areas would be the paranotae.

Mesoscutellum. — This is large, extending along the caudal margin of the mesonotum. To its caudal margin is attached the metacoria (*mco*, Figs. 59–61). Its mesal portion is expanded to form an elevated shield-shaped mesoscutulis (*msu*, Figs. 59–69), which primitively is probably exposed as a triangular area between the bases of the elytra and the base of the epinotum (Enhydrus, Andogyrus, Macrogyrus, Orectochilus, Orectogyrus and Gyrinini). In Dineutus, Porrhorrhynchus and Gyretes, the mesoscutulis is obscured by the lobing of the mesal portion of the posterior margin of the epinotum, and this has apparently allowed it to deviate from its primitively triangular form (Fig. 65). In Dineutus it is noticeably less triangular in outline than in Enhydrus, and in Porrhorrhynchus it is transversely quadrate with a bilobed caudal margin. The condition in Orectochilus (Fig. 66) approaches that of Enhydrus, but in the other orectochilin genera (Figs. 65, 67) it is transverse and so cephalocaudally compressed as practically to lose its triangular form. In Gyretes a transverse ridge divides it into subequal anterior and posterior areas. In Gyrinini (Fig. 62) its triangularity is decidedly accentuated.

The mesoscutulis is an elevated and expanded plate, so that on all sides its margins are strongly infolded, forming a system of ridges and lamellae on the ental surface of the mesonotum (*msur*, Figs. 63, 66, 69). Especially wide is the reduplication of the caudal margin, and it is to the cephalic margin of this reduplication that the metacoria is attached (*lmc*, Fig. 63). The lamella associated with the infolding of the anterior margin of the mesoscutulis, the mesoparaphragma, is continuous with the lamella of the mesal suture of the mesoscutum. Laterally the mesoscutellum extends in a pair of narrow mesoparascutules (*msct*, Figs. 59–63, 65–69), whose extreme lateral portions constitute the transversely striated mesospirales (*msl*, Figs. 59–62, 65–69), axillary cords, which extend out into the mesalulae (*msa*, Figs. 59, 61, 62, 66) or axillary membrane.

Elytra (Figs. 59, 61, 62, 66, 70–79) *articulation.* — The elytron

articulates with the mesonotal and mesopleural wing-processes by means of a distinct knob, the elytral artis (*el*, Figs. 59, 61, 62, 66), closely associated with which are one or two irregularly shaped, semifused or independent plates which undoubtedly represent the mesoduritae (*msd*).

Shape. — The elytra varies from being nearly rounded caudad (Enhydrus and certain Dineutus) to a more or less complicated emarginate, truncate, or spinose condition in the other forms.

Sculpture. — Elytra nine-striated in Enhydrini; clearly shown in certain Enhydrus, Dineutus and Andogyrus; partially obliterated in certain Dineutus, Andogyrus and Macrogyrus; obsolete in Porrhorrhynchus and many Dineutus. Elytra of Orectochilini without striae, lateral margins always and occasionally the entire upper surface pubescent; in certain Orectogyrus the non-pubescent areas are distinctly elevated above the pubescent surface. Elytra eleven-striated in Gyrinini, present as deep furrows in Aulonogyrus, as rows of punctures in Gyrinus, with a tendency for the more mesal striae to become obsolete in both genera. No one of these conditions can serve as the point of departure for the other two.

Laterad the elytron is inflexed to form a moderately wide hypomera, which embraces the lateral margin of the meso- and metathorax and the basal segments of the abdomen.

Locking. — The four methods (Breed and Ball, 1908, pp. 289–303) for interlocking the elytra of Coleoptera are present in Dineutus. The specimens were imbedded in paraffin and cut into thick sections with a safety razor blade. They were studied without removing the paraffin except from the cut surfaces.

(1) Along the suture the elytra interlock by means of a distinct tongue-and-groove arrangement, as shown in Figures 70 and 71, the tongue being on the right elytron and the groove on the left.

(2) The notopterae form a pair of longitudinally parallel grooves on the dorsum of the metathorax, between which fit the swollen inner sutural edges of the elytra as shown in Figure 70.

(3) The mesal anterior margin of the elytra slips under the

posterior margin of the mesoscutulis. The posterior margin of the epinotum fits over the mesoscutulis and the entire anterior margin of the elytra. These two factors combine to hold the basal portions of the elytra in place.

(4) Figures 72 to 77 show the manner in which the hypomera adapts itself to the lateral margin of the body. Figures 72 to 74 are sections through the region of the metaepisternum. Figure 73 is through the complicated groove about half-way back on the metaepisternum that interlocks with a process of the hypomera, a much more highly developed locking device than any figured by Breed and Ball. These authors describe a *musculus episternalis* which is attached to the metaepisternum, the contraction of which is said to cause the metaepisternum to move so as to release the elytra. Figures 75 to 77 are sections through some of the more basal abdominal segments. They show that in the four basal abdominal sterna there is a considerable adaptation between the hypomera and the latasternites.

(5) In addition to these devices, it seems probable that the fitting of cavities in the region of the humerus of the elytra over lobes of the mesopleuron is instrumental in locking the elytra. Figure 78 illustrates the lobing in this region in Gyretes. Figure 79 illustrates the anterior portion of the hypomera of the elytra. It seems probable that the fitting of the cavity (y) in the hypomera over the lobe (y') of the mesopleuron may aid somewhat in keeping the elytron in place.

Metanotum (Figs. 80–82). — The metanotum consists of four parts, the metapraescutum (confined to the metapraephragma, *mpp*, of the mesal portion of the cephalic margin), the metascutum (*mcu*), the metascutellum, and the metapostscutellum.

Metascutum. — This constitutes the greater portion of the dorsal aspect of the metanotum with the exception of the mesally situated notal groove (*ng*), which is generally considered to constitute a portion of the metascutellum, the metascutulis (*mu*) (Snodgrass, 1909, p. 563; Van Zwaluwenburg, 1922, p. 19; Hayes, 1922, p. 14). MacGillivray (1923, p. 198) designates the ridges that bound the metascutulis on either side the notopterae (*np*); the area between he calls the notopteraria and considers it

a portion of the metascutum. Except in Gyrinini, the metascutulis completely divides the metascutum and itself attains the metacoria. In the Gyrinini (Fig. 82) the right and left portions of the metascutum apparently fuse cephalad of the metascutulis. The distinct tubercular knob at the cephalo-lateral angle of the metascutum is the medalaria (*mn*, Figs. 80–84, 88). As in the mesonotum, the caudalaria is not well developed, but is represented by a slight lobing (*mcd*) of the posterior lateral margin of the metascutum. The metascutum is traversed transversely by a groove originating at the notoptera and extending a variable distance laterad, with corresponding ridges on the entad surface.

Metascutellum. — Except in Gyrinini the margins of the metascutulis (*mu*, Figs. 80–82) are throughout distinctly and widely reduplicated together with the margins of the adjacent portions forming distinct lamellae, and the notopterae are prolonged caudad of the posterior margin of the metanotum in a pair of distinct points. Both these features are wanting in the Gyrinini; the margins of the metascutulis are little reduplicated and the notopterae terminate at or before the caudal margin. Laterad the metascutellum extends as narrow metaparascuteles (*mct*) to the margin of the metanotum where they form metaspirales (*ml*) that extend into the metanotacoria. The connection between the metaparascuteles and the metascutulis is extremely narrowed or entirely obliterated ectally by the caudal extension of the notoptera. Entad, however, they are continuous. Immediately anterior to the metaspiralis, a distinct and rather elongate metascutalaria (*mtl*, Figs. 80, 83–84, 88) extends forward obliquely into the notarotaxis. Such is the homology indicated by MacGillivray's figure (1923, p. 156) and by his further statement that the scutalaria articulates with the terminalia or third axillary sclerite. Snodgrass's figures (1909, Figs. 127, 132–136, 140, 142, 193, 198) indicate that this is the structure he regards as the posterior notal wing-process, a process of the scutum (*ibid.*, p. 530).

Metapostscutellum (*mpc*, Figs. 80–84, 88). — This extends as a narrow transverse sclerite along the caudal margin of the metascutellum. Mesad it is not visible ectally, forming the metapost-

phragma which is closely associated with the caudal reduplication of the metascutellum. Laterad it emerges from beneath the metascutellum and at its lateral extremities is gradually but immensely expanded in a membranous area that extends on the latus posterior to the line of attachment of the metawing, to the dorsal margin of the supraepimeron and is continuous cephalad with the metanotacoria that is quite extensive at this point.

Wings (Figs. 83–84, 88–96): *pteraliae* (Figs. 83, 84, 88).— Four duritae appear to be present. The large sigmoidea (*si*) or first axillary sclerite lies along the lateral margin of the metascutum; it is divided transversely and articulates against the metamedalaria (*mn*) and the metacaudalaria (*mcd*). Along the anterior portion of its distal margin lies the submedia (*smd*) or second axillary sclerite. More distad and closely associated with the analis (*an*) or fused proximal portion of the anal veins is the terminalia (*tm*) or third axillary sclerite, which articulates against the distal end of the metascutalaria (*mtl*). Between the terminalia and the sigmoidea is a small sclerite that may possibly be interpreted as a navicula (*nv*) or fourth axillary sclerite.

Of the venellae, the costalis (*co*) is indicated along the proximo-cephalic margin of the wing. The radialis, formed by the fusion of subcosta, radius and media, is too distad to be represented in the figures. Analis (*an*) well developed. The triangular area of chitinization between the submedia and the analis just anterior to the terminalia is interpreted as one of the funditae, the mediella (*md*).

In Orectochilini (Fig. 84) the pteraliae tend to decrease in size and degree of chitinization so as to become almost indistinguishable from the surrounding membrane, but they are all present.

Shape (Figs. 89–96).— In Gyrinini (Figs. 94, 95) the wing is distinctly broader in proportion to its width with a more broadly rounded caudal margin than in the other tribes.

Venation (Figs. 89–96).— Venation closely similar to that of such adephagids figured by Forbes (1923, p. 348, Plate 31) as Galerita, Harpalus and Haliplus, and the homologies have been determined from these figures. Forbes (*ibid.*, p. 337) points out

that a feature that seems to be characteristic of Gyrinidae is "a thickening above the outer part of the stem of M, of uncertain significance. It might be interpreted as a trace of M_{1+2}, but this would not lead to any logical working out of the distal part of the wing." This thickening (*th*) can be traced throughout the family, though it is quite faint in some of the genera. The intrafamily variation concerns itself very largely with the region of the anal veins. Enhydrus represents a type from which all the others can be derived by a process of reduction.

From Enhydrus (Fig. 89) Dineutus and Porrhorrhynchus (Fig. 90) are distinguished by the loss of the tip of Cu (*tp*). According to Bernet Kempers (1923, p. 72, Fig. 87), *P. marginatus* is further distinguished from Enhydrus and *P. landaisi* Rég. by the loss of $4A_1$.

Andogyrus (Fig. 91) and Macrogyrus are distinguished from Enhydrus by the loss of the tip of Cu, the elimination of the wedge-cell (*W*) between $2A_3$ and $3A_1$, and the loss of the stem of $3A_2$, an approach in important respects to Gyrinini.

The Orectochilini (Figs. 92–94) are distinguished from Enhydrus by the elimination of the wedge-cell (*W*), and of $3A_2$, and a tendency towards the reduction of $1A$ and $2A_2$. This process has reached an extreme in Gyretes (Fig. 94) in which only a single stem remains to represent the two veins. The connection of these two veins is somewhat broken in Orectochilus (Fig. 92) and Orectogyrus (Fig. 93). The stem of M_4 has disappeared in Orectogyrus.

The Gyrinini (Figs. 95, 96) are distinguished from Enhydrus by the loss of the tip of Cu, the elimination of the wedge-cell (*W*), the tendency of $2A_2$ to break away from $1A$ and of $3A_2$ and $4A_1$ to fuse. In the last two respects, Aulonogyrus (Fig. 95) appears to be somewhat more modified than Gyrinus (Fig. 96). In Aulonogyrus $2A_2$ is less distinct and the separation of $3A_2$ from $3A_1$ and its fusion with $4A_1$ are more complete.

Forbes (1923, p. 337) noted that the tip of Cu (*tp*) was preserved only in Peltodytes (Haliplidae) and Pelobiidae among the Adephaga known to him. Bernet Kempers (*loc. cit.*) figures it for numerous Dytiscidae. Its occurrence in Enhydrus together

with its repeated occurrence in other Hydrocanthari (Hydradephaga) is further evidence of the phylogenetic unity of the group. Its occurrence in Gyrinidae is primary and not secondary.

Abdomen and Appendages

Abdomen (Figs. 85–87, 97–102). — The abdominal formula is $\frac{T1\ T2\ T3\ T4\ T5\ T6\ T7\ T8}{S2\ S3\ S4\ S5\ S6\ S7\ S8}$. The unasternum is wanting.

Sterna. — Between the dua-, tre-, and quasterna the coriae have become reduced to sutures and the segments have become immovable. There is a strong tendency for the tresternasuture to become more or less obsolete (Figs. 97–101). It is entire in Enhydrus (Fig. 89), though its mesal portion is quite faint. It is rudimentary in the remaining enhydrin genera (Figs. 90, 91) and is practically absent in the Orectochilini (Figs. 92–94). It is entire in Aulonogyrus (Fig. 100) and is obsolete mesally in Gyrinus. There is a pair of cephalad extending quaprevenplicae (*q*) present in the Gyrinini (Figs. 44, 100) and in the Orectochilini (Figs. 42, 101) except Orectogyrus (Fig. 43), which are absent in the Enhydrini. Simple prevenplicae and postvenplicae are present on the movable sterna. They form the lines of attachment for the intersternal coriae. The metacoxae completely obscure the mesal portion of the duasternum, and in Orectochilini and Gyrinini encroach considerably or entirely over the mesal portion of the tresternum, evidence of antero-posterior compression in these groups. The dua-, tre-, qua-, and quisterna are divided into a ventral mesasternite (*mcx*) and a lateral latasternite (*lc*, Figs. 50, 75, 100, 102). The latasternite is closely adapted to the inner margin of the hypomera as mentioned above (Figs. 78, 79).

In Orectochilini the abdominal segments, especially the more caudal ones, are more elongate than in the other groups (Figs. 42, 43, 86). This is correlated with the much narrower body of this group. The eighth and caudal segment in particular is in the shape of a cone. A row of vertical setae that are almost as long as the abdomen is thick traverse the octasternum and the

caudal half of the septasternum (Figs. 42, 43). These may have something to do with steering the animal.

Terga (Figs. 85–87, 102). — Eight terga are present. In general they gradate from the entirely or nearly entirely membranous basal ones to the caudal ones exposed by the elytra that are practically as heavily chitinized as the rest of the body. In the Gyrinini not even the basal terga appear to be entirely membranous, and in the Orectochilini the basal five — the fifth is feebly chitinized in Orectogyrus — are membranous. The Enhydrini present an intermediate condition in which the basal two or three terga are membranous, the intermediate two or three are increasingly strongly chitinized, and the caudal three, as in all the groups, are strongly chitinized.

The figure (Fig. 85) of the ental surface of the terga of Dineutus shows that each tergum but the terminal one possesses a pair of lobular predorplicae (*p2*, *p3*, etc.) and a single postdorplica (*pd2*, *pd3*, etc.). Except in the unatergum, it was impossible to find the paired lobular predorplicae in the other genera. Apparently in the more specialized groups they have become lost as the individuality of the separate terga has been merged, though this does not account for their absence in Enhydrus. The postdorplicae are fairly constant on the more caudal terga.

Latacoriae (Figs. 86, 87, 102). — The latacoriae (*l1*, *l2*, etc.), except the first, are separated from the terga by a fold which approximates the form of a true suture as the latella approaches the tergum and the tergum becomes more chitinous. The unacoria is, however, continuous with the unatergum. Towards the caudal end of the body the latacoriae exhibit the same tendency as do the terga to increase the extent of their chitinization. The chitinized area is a latella (*lt4*, *lt5*, etc., Figs. 87, 102). The latacoriae of the three basal segments are always entirely membranous. The fourth is entirely membranous except in Enhydrini. The fifth is membranous in Aulonogyrus, and both fifth and sixth are membranous in Gyrinus. The seventh latacoria is entirely chitinous, a latella, except in Orectochilini where it is absent. The eighth is always obsolete. Where the

fourth, fifth and sixth latacoriae have latellae, there is a gradual increase in the area occupied by it as one proceeds caudad. The posterior lateral angle of the latacoria becomes chitinized first, and the area of chitinization gradually spreads until only the anterior mesal angle is left membranous.

Spiracles (Figs. 86, 87, 102). — In or near the latacoriae are located the eight pairs of abdominal spiracles (*sp1*, *sp2*, etc.), all of them open and apparently functional. The first six pairs are located in the membrane of the latacoriae and are, with the exception of the unaspiracles, situated towards the cephalic margin of the segment. The septa- and octaspiracles are located in the extreme anterior angles of their respective terga. The sexaspiracles are somewhat intermediate in position, being extremely close to the margin of the sexatergum. All the spiracles are small with the exception of the unaspiracles (*sp1*), which are large and elongate oval. The unaperitreme forms a large pronounced tubercle on the membrane of the unacoria just dorsad to the supraepimeron.

Genitalia. — The terminal abdominal segments are modified by reduction. The eighth is normal, forming the terminal segment of the body and very little telescoped into the seventh. The ninth and tenth segments are wanting or represented by coriae.

Male genitalia (Figs. 103–106). — The male genitalia or aedeagus (cf. Sharp and Muir, 1912, p. 484) consist: (1) of a median lobe (*mlb*) bearing on its ventral surface the median orifice or meatus; (2) of a pair of flattened lateral lobes (*llb*) or claspers, which are slightly longer than the median lobe, bear hairs along their distal margins, are consolidated along their ventral basal half and near the base on the dorsal side, and are articulated with the base of the median lobe on their dorsal side; and (3) of a large basal piece (*bp*) which forms a chitinous plate on the ventral and lateral aspects, but which is mostly membranous on the dorsal surface. The basal piece is connected with the median and lateral lobes by a large connecting membrane which allows for great freedom of movement.

The coria between the octasternum and the aedeagus repre-

sents the novasternum, and the coria between the aedeagus and the anus represents the remaining sternum or sterna of the body.

The lateral lobes in Orectochilini (Fig. 105) are distinctly narrower than in the other tribes. In Gyrinus the apex of the lateral lobes is slightly more truncate than in the other genera. The median lobe is quite variable, but in view of the extreme variation shown in a single genus (Fall, 1922, Pl. XVI), one may question the significance of such a variation as that illustrated in the figure for the aedeagus of Andogyrus (Fig. 104).

On the basis of their comparative study of genitalia, Sharp and Muir (1912, pp. 614–616) suggest that the Gyrinidae, in view of their well-developed tegmen (basal piece plus lateral lobes), be associated with the Hydrophilidae under the superfamily Byrrhoidea rather than with the Caraboidea, characterized by a reduced tegmen, where their other characters place them. The well-developed tegmen is considered a generalized feature. The possibility is suggested here that a reduced has been mistaken for a generalized condition.

Female genitalia (Figs. 107–109). — These consist of a pair of flattened lateral lobes (*llb*) bearing a fringe of hairs along their distal margins and each articulating towards its baso-lateral angle with a slender elongate sclerite. Between the lobes is the vagina. The similarity between the female lobes and those in the aedeagus is suggestive, but only very questionably so, of some homology between them. Other structures, as valvae, are wanting.

In Enhydrini (Fig. 107) the lateral lobes are more oval than in either of the two remaining groups. In Orectochilini (Fig. 108) the lobes are extremely long and narrow. In Gyrinini (Fig. 109) the apices of the lobes are subtruncate, giving a subquadrate appearance to the lobe as a whole.

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SUPPLEMENTARY NOTE

Georg Ochs on Gyrinid Phylogeny. — Since writing this paper I have received the first portion of a monograph of Dineutus for the world (Ochs, 1926), including analytical keys to the species. In it the author maintains that the Gyrinidae are related to none of the existing groups of Coleoptera, that the Gyrininae constitute the most primitive gyrinid living on standing water and pupating on emergent vegetation, and that from these were derived in independence of each other the Enhydrinae and Orectochilinae in which the tendency is towards running water,[1] and in which the place of pupation shifts from emergent vegetation to under cover along the shore-line. The more primitive dineutins are the small forms of gyrinoid fascies, the more derivative those of large size and broadly oval form, exactly opposite to what I have found (Hatch, 1926).

Ochs has been led to his view of the distinctness of the Gyrinidae as well as the distinctness of Orectochilinae from Enhydrinae by an overemphasis of their peculiarities. The essential thing to emphasize in comparative studies is similarity with other types. Differences can always be accounted for in terms of the great plasticity of living matter. But true similarities must be explained as homologies. The genitalia, as I have pointed out, present the only real objection to the dytiscoid affinities of Gyrinidae, and they may be secondarily reduced.

The morphological evidence for Ochs' scheme of dineutin phylogeny is: (1) the cosmopolitanism of Gyrinus, (2) the eleven-striated gyrinin elytron which by reduction is supposed to give rise to the nine-striated enhydrin elytron, and (3) the small size of Gyrinus coupled with the idea that there is a general tendency for insects to increase in size in the course of their evolution. As further evidence of the primitiveness of the small narrow Dineutus and the derivativeness of the larger species, Ochs cites the absence of sensory bristles on the profemur in the male of Dineutus (*s. str.*) and their great reduction in the Australasian subgenera.

Size and distribution are significant only as correlated with structural features, and to argue from mammals to insects is invalid. I have presented the morphological motives for my alternative scheme in full (Hatch, 1926) and since Ochs has adduced no really new evidence, there is no need to go into the subject again here.

The subgenus Gyrinodineutus Ochs includes the type of the subgenus Spinosodineutes Hatch and must be considered synonymous with it. In Dineutus (*s. str.*) the microsculpture of the peripheral groups (Madagascan, Indomalayan, North American) is similar, and different from that of the central Ethiopian group. May not this be accounted for by supposing that the present peripheral groups represent the former condition of the subgenus and that subsequent to their migration from the Ethiopian center further modification occurred in the stock that remained there?

In order to make known to American students the subgenera and groups

[1] The still water Enhydrinae are apparently regarded as remigrants. This is probably much nearer the truth than I have previously suspected (Hatch, 1925, p. 104; 1926, p. 443).

into which Ochs divides Dineutus, I present the following table, but have arranged it to accord with my concept of their phylogeny. Reference should be made to the original for details.

A¹. Elytral apex not truncate, rarely with one or two spines
  B¹. Elytra microreticulate only
    C¹. Broadly oval, size large, over 12 mm.
      D¹. Broadly oval
        Indomalayan and North American groups of Dineutus (*s. str.*)
      D². Somewhat narrowed in front
        Madagascan group of Dineutus (*s. str.*)
    C². Narrower; under 12 mm. long; North America....Cyclinus Kby.
  B². Elytra microreticulate and micropunctate
    C¹. Larger, broadly oval........Ethiopian group of Dineutus (*s. str.*)
    C². Smaller, more narrowly oval; Africa to India..Protodineutus Ochs
A². Elytral apex truncate
  B¹. Labrum broad, not elongate; elytral apex not more than bispinose
    C¹. Form rhomboidal; external angle of elytra frequently not prominent
      D¹. Disc of elytra not strigose
        E¹. Form distinctly rhomboidal, size large to moderate; New Guinea, New Britain...............Rhombodineutus Ochs
        E². Form subrhomboidal
          F¹. Size moderate; Celebes.............Paracyclous Ochs
          F². Size small; Australia to Philippine Is.....Cyclous Esch
      D². Disc of elytra strigose; Fiji Is..........Callistodineutus Ochs
    C². Form narrower; external angle of elytral truncature prominent; Africa to Japan
        Spinosodineutes Hatch (Gyrinodineutus Ochs)
  B². Labrum triangular; elytral apex multispinose
    C¹. Smaller; protibia with scattered sense hairs; yellow margin of dorsum without black spot in front; New Guinea
        Rhomborhynchus Ochs
    C². Larger; protibia with bunches of sense hairs; yellow margin of dorsum with dark spot in front; Indomalayan
        Porrhorrhynchus Rég.

Herr Georg Ochs has kindly pointed out to me some corrections to be made to my report (Hatch, 1925) published in Volume V of these Papers: (p. 447) Two Ethiopian species of the subgenus Cyclous (*Dineutus fauveli* Rég. and *D. dunckeri*) have an apical elytral spine as has Spinosodineutes, but lack testaceous margins to thorax and elytra. This reduces the peculiarity of Spinosodineutes to this single character and perhaps invalidates it as a subgenus, though its species remain at the apex of this line of development, and its Ethiopian affinities are emphasized. (p. 448) A single species of Dineutus (*s. str.*) (*D. machrochirus* Rég.) from New Guinea decreases the geographic isolation of the primitive members of the subgenus Cyclous. (p. 451) *Macrogyrus gouldi* Hope is a second Macrogyrus with prothorax and elytra bordered with yellow.

Herr Ochs further informs me that he knows of *Macrogyrus howitti* Clark from Tasmania, which is to be expected if the genus be derived from the

South American Andogyrus, and *M. sumbawae* Rég. from southern Celebes. These data require this region, as well as Sumbawa and Timor, to be considered transitional between the Australasian and Oriental regions.

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ABBREVIATIONS USED IN PLATES

a, antenna; *ac*, antacava; *af*, antafossa; *ag*, antennal groove; *al*, auricular lobe of pedicel; *an*, analis; *ar*, antacaval ridge.

b, bulbus of scape; *bp*, basal piece; *bs*, basistipes.

C, costa; *c*, crassa; *ca*, cardo; *cc*, cervacoria; *ccs*, cervepisternum; *cl*, clypealia; *co*, costalis; *cp*, cardoprocess; *cs*, caudal surface of mandible; *ct*, corpotentorium; *Cu*, cubitus; *cu–a*, cubito-anal cross-vein; *cx*, coxa; *cxa*, coxartis; *cxc*, coxacoila.

d, disc attached to metatrochantin; *dce*, dorsal compound eye; *dd*, dorsal distadentis; *ds*, dorsal surface of mandible.

e, epicranium; *ea*, epicranial arms (within clypofrons); *eg*, epigusta; *el*, elytron; *ela*, elytral artis; *ell*, left elytron; *elr*, right elytron; *eo*, exoculata; *ep*, epipleuron; *et*, extensotendon of mandible; *ex*, epipharynx.

f, flagellum; *fc*, flagellacoria; *fe*, femur; *fh*, fulcrum hypopharyngeum; *fr*, frontal ridge; *fs*, femasuture; *fur*, furrow.

g, groove; *gl*, galea; *gp*, gular parademe; *gu*, gula; *gub*, gular bar; *gus*, gular suture.

h, hypostoma; *hu*, humerus of elytron; *hx*, hypopharynx; *hy*, hypomera.

iml, intermetacoxal lamella; *ims*, intermetacoxal suture.

l, labrum; *la*, lacinia; *lac*, lacinarastra; *lc*, latacoxa; *lc2*, line of attachment of duacoria; *li*, labium; *ll*, lateral lobe of submentum; *llb*, lateral lobe; *lm*, line of attachment of mesocoria; *lma*, lamella; *lp*, labial palpus; *lpf*, labial palpifer; *ls*, latasternite; *ls2*, dualatasternite; *ls3*, trelatasternite; *ls4*, qualatasternite; *lt*, laminatentorium; *lt4*,

qualatella; *lt5*, quilatella; *lt6*, sexalatella; *lt7*, septalatella; *lw*, line of attachment of wing; *l1*, unalatacoria; *l2*, dualatacoria; *l3*, trelatacoria; *l4*, qualatacoria; *l5*, quilatacoria; *l6*, sexalatacoria; *l7*, septalatacoria.

M, media; M_1, first branch of media; M_4, fourth branch of media; *m*, mandible; *mb*, membrane; *mc*, maxacoria; *mcd*, metacaudalaria; *mcf*, metacoxafossa; *mcms*, metaepisterno-metacoxal suture; *mco*, metacoria; *mcp*, metacoxal process; *mcr*, metacoxacarina; *mcs*, metacoxacrista; *mcsl*, metacoxasulcus; *mct*, metaparascutulis; *mcu*, metascutum; *m-cu*, medio-cubital cross-vein; *mcx*, metacoxa; *mcxp*, metacoxal parademe; *mcxr*, posterior reduplication of metacoxa; *md*, mediella; *mepi*, metaepimeron; *mer*, metaepisternal ridge; *mesn*, metanotepisternum; *mess*, metasternepisternum; *mest*, metaepisternum; *mf*, metafurca; *ml*, metaspiralis; *mlb*, median lobe; *mm*, metamedalaria; *mml*, metasterno-metacoxal lamella; *mn*, metanotum; *mng*, marganotum; *mp*, maxillary palpus; *mpc*, metapostscutellum; *mpf*, maxillary palpifer; *mpg*, metapostphragma; *mph*, metaprephragma; *mpl*, metacoxa-metaepisternal lamella; *mpp*, metapreparapteron; *mpr*, metaprescutum; *mps*, metapleural suture.

ms, median surface of mandible; *msa*, mesoalulae; *msc*, mesocoria; *mscc*, mesocoxacava; *mscd*, mesocaudalaria; *mscf*, mesocoxafossa; *msci*, mesocoxacrista; *mscp*, mesocoxal process; *mscr*, mesocoxacarina; *mscsl*, mesocoxasulcus; *msct*, mesoparascutulis; *mscx*, mesocoxa; *msd*, mesodurita; *msepi*, mesoepimeron; *msepr*, mesoepisternal ridge; *msest*, mesoepisternum; *msf*, mesofurca; *msfc*, mesofemacava; *msl*, mesospiralis; *msm*, mesomedalaria; *msn*, mesoentopleuron; *msp*, mesosternal parademe; *mspc*, mesopraescutum; *msph*, mesoprephragma; *msplr*, mesopleural ridge; *mspls*, mesopleural suture; *mspn*, mesonotepimeron; *mspp*, mesopreparapteron; *msps*, mesosternepimeron; *msr*, metasternasuture; *msrl*, metasternasutural lamella; *mss*, mesospiracle; *mssl*, mesosternal lamella; *mssn*, mesonotepisternum; *msss*, mesosternepisternum; *msstn*, mesosternannum; *mst*, mesoscutum; *mstl*, metasternal lamella; *mstn*, metasternannum; *mstr*, mesosternite; *msts*, mesosternal suture; *msu*, mesoscutulis; *msur*, reduplication of mesoscutulis; *mswp*, mesopleural wing process; *ms2*, duamesosternite; *mt*, metatentorium; *mtl*, metascutalaria; *mtnl*, metatentorial lobe; *mts*, mentasuture; *mu*, metascutulis; *mwp*, metapleural wing process; *mx*, maxilla.

ng, notal groove; *np*, notoptera; *nt*, notaxis; *nv*, navicula.

O, oblong cell (2nd M); *oc*, occiput; *ocp*, occipital parademe; *ol*, oculata; *os*, occipital suture.

p, pedicel of antenna; *pa*, preartis; *par*, parartis; *pc*, postcoila; *pcc*, procoxacava; *pcxf*, procoxafossa; *pcxp*, procoxal process; *pd*, proxadentis; *pd2*, duapostdorplica; *pd3*, trepostdorplica; *pd4*, quapostdorplica; *pd5*, quipostdorplica; *pd6*, sexapostdorplica; *pd7*, septapostdorplica; *pepi*, proepimeron; *pest*, proepisternum; *pfc*, profemacava; *pfr*, profemacaval ridge; *pfrc*, profurca; *pfri*, profurcina; *pg*, post-

gena; *pgp*, pregular parademe; *pln*, pleuronotum; *plr*, pleurotaxis; *plt*, pleurotaxis; *pn*, pretentorina; *po*, postclypeus; *ppls*, propleural suture; *pr*, precoila; *prns*, pronotal suture; *psr*, pseudofrontal ridge; *pstn*, prosternannum; *pt*, pretentorium; *ptc*, postartis; *ptl*, postcoila; *p1*, unapredorplica; *p2*, duapredorplica; *p3*, trepredorplica; *p4*, quapredorplica; *p5*, quipredorplica; *p6*, sexapredorplica; *p7*, septapredorplica; *p8*, octapredorplica.

q, quaprevenplica.

R, radius; R_1, first branch of radius; R_2, second branch of radius; R_{4+5}, fourth plus fifth branches of radius; *r*, mesoepisternal ridge; *ra*, radial cross-vein; *ri*, ridge; *r-m*, radio-medial cross-vein; *Rs*, stem of radial sector; *rt*, rectotendon.

s, row of vertical setae; *Sc*, subcosta; *sc*, scape of antenna; *scr*, scrobe; *se*, supraepimeron; *sel*, suture of elytra; *sg*, subgalea; *sgla*, subgaleolacinia; *si*, sigmoidea; *sl*, salivia; *sm*, submentum; *smd*, submedia; *sp*, point of attachment of stipital plica; *sp1*, unaspiracle; *sp2*, duaspiracle; *sp3*, trespiracle; *sp4*, quaspiracle; *sp5*, quispiracle; *sp6*, sexaspiracle; *sp7*, septaspiracle; *sp8*, octaspiracle; *sr*, supraocular ridge; *st*, fused stipulae; *stg*, pterostigma; *str*, sternite; *su*, subgusta; *s2*, duasternum; *s2c*, duacoria; *s3*, tresternum; *s3s*, tresternasuture; *s4*, quasternum; *s4s*, quasternasuture; *s5*, quisternum; *s5s*, quisternasuture; *s6*, sexasternum; *s7*, septasternum; *s8*, octasternum.

t, tibia; *ta*, tarsus; *tac*, tarsacoila; *tar*, tibiartis; *ta1*, unatarsomere; *ta1a*, unatarsartis; *ta2*, duatarsomere; *ta2a*, duatarsartis; *ta2c*, duatarsacoila; *ta3*, tretarsomere; *ta3a*, tretarsartis; *ta3c*, tretarsacoila; *ta4*, quatarsomere; *ta4a*, quatarsartis; *ta4c*, quatarsacoila; *ta5*, quitarsomere; *tcl*, tibiacoila; *tex*, tendons of the extensors of the head; *tf*, tibiaflexis; *th*, thickening above media; *tm*, terminalia; *tn*, trochantin; *tp*, tip of cubitus; *tr*, trochanter; *t1*, unatergum; *t2*, duatergum; *t3*, tretergum; *t4*, quatergum; *t5*, quitergum; *t6*, sexatergum; *t7*, septatergum; *t8*, octatergum.

vce, ventral compound eye; *vd*, ventral distadentis of mandible; *vs*, ventral surface of mandible.

W, wedge-cell (*2nd 2A*).

y, ***y′***, locking device.

1 A, first anal vein; *1–2a*, cross-vein between first and second anal vein.

2 A, second anal vein; $2A_1$, $2A_2$, $2A_3$, branches of second anal vein; *2–3a*, cross-vein between second and third anal vein.

3 A, third anal vein; $3A_1$, $3A_2$, branches of third anal vein.

4 A, fourth anal vein; $4A_1$, $4A_2$, $4A_3$, branches of fourth anal vein.

EXPLANATION OF PLATES

PLATE XX

1–5. Dorsal aspect of head: (1) Dineutus, (2) Porrhorrhynchus, (3) Orectochilus, (4) Orectogyrus, (5) Gyrinus

6. Ventral aspect of head: Porrhorrhynchus

7–15. Lateral aspect of head: (7) Enhydrus, (8) Dineutus, (9) Porrhorrhynchus, (10) Andogyrus, (11) Orectochilus, (12) Orectogyrus, (13) Gyretes, (14) Aulonogyrus, (15) Gyrinus

16. Lateral aspect of head to show tentorium: Porrhorrhynchus

17–18. Dorsal aspect of head to show tentorium: (17) Porrhorrhynchus, (18) Orectogyrus

19. Caudal aspect of tentorium: Dineutus

20–22. Antenna: (20) Enhydrus, (21) Porrhorrhynchus, (22) Andogyrus

PLATE XXI

23–26. Antenna: (23) Macrogyrus, (24) Orectochilus, (25) Orectogyrus, (26) Gyrinus

27–28. Ventral aspect of mandibles: (27) Dineutus, (28) Gyrinus

29–30. Dorsal aspect of dextral mandible: (29) Porrhorrhynchus, (30) Orectochilus

31–32. Ventral aspect of maxilla: (31) Gyretes, (32) Gyrinus

33. Dorsal aspect of maxilla: Enhydrus

34. Ventral aspect of labium: Dineutus

35. Epipharynx: Dineutus

36. Hypopharynx: Dineutus

37–38. Ventral aspect of prothorax: (37) Enhydrus, (38) Orectochilus

39. Caudal aspect of prothorax: Enhydrus

40–42. Ventral aspect of mesothorax, metathorax, and abdomen: (40) Enhydrus, (41) Porrhorrhynchus, (42) Orectochilus

PLATE XXII

43–44. Ventral aspect of mesothorax, metathorax, and abdomen: (43) Orectogyrus, (44) Gyrinus

45. Facets of dorsal eye: Dineutus

46. Facets of ventral eye: Dineutus

47. Ental surface of ventral aspect of mesothorax and metathorax: Porrhorrhynchus

48. Dorsal aspect of metafurca: Aulonogyrus

49. Mesopleuron: Enhydrus

50. Metapleuron: Dineutus

51–52. Propods of Enhydrus: (51) Female, (52) Male

53. Protrochantin: Enhydrus

54. Mesopod: Enhydrus

55. Metapod: Enhydrus

56. Mesopod: Aulonogyrus
57. Metapod: Aulonogyrus
58. Antenna: Dryops striatopunctatus Heer
59–62. Mesonotum: (59) Enhydrus, (60) Porrhorrhynchus, (61) Andogyrus, (62) Aulonogyrus
63–65. Ental surface of mesonotum: (63) Enhydrus, (64) Porrhorrhynchus, (65) Orectogyrus

PLATE XXIII

66–67. Mesonotum: (66) Orectochilus, (67) Gyretes
68–69. Ental surface of mesonotum: (68) Orectochilus, (69) Aulonogyrus
70–71. Cross-sections through elytral suture of Dineutus: (70) level of metanotum, (71) posterior to metanotum
72–77. Cross-sections through margin of elytra of Dineutus: (72) anterior portion of metaepisternum, (73) middle portion of metaepisternum, (74) posterior portion of metaepisternum, (75) level of duasternum, (76) level of tre- or quasternum, (77) level of qui-, sexa-, or septasternum.
78. Mesopleural suture: Gyretes
79. Anterior portion of hypomera: Gyretes
80–82. Metanotum: (80) Porrhorrhynchus, (81) Orectogyrus, (82) Aulonogyrus
83–84. Notorotaxis: (83) Enhydrus, (84) Orectogyrus
84. Ental surface of dorsal aspect of abdomen: Dineutus
86–87. Dorsal aspect of abdomen: (86) Gyretes, (87) Gyrinus

PLATE XXIV

88. Notorotaxis: Aulonogyrus
89–96. Wings: (89) Enhydrus, (90) Porrhorrhynchus, (91) Andogyrus, (92) Orectochilus, (93) Orectogyrus, (94) Gyretes, (95) Aulonogyrus, (96) Gyrinus
97–101. Tresternasuture: (97) Enhydrus, (98) Porrhorrhynchus, (99) Andogyrus, (100) Aulonogyrus, (101) Orectochilus
102. Dorsal aspect of abdomen: Dineutus
103–106. Male genitalia: (103) Enhydrus, (104) Andogyrus, (105) Orectochilus, (106) Aulonogyrus
107–109. Female genitalia: (107) Enhydrus, (108) Orectogyrus, (109) Aulonogyrus

PLATE XX

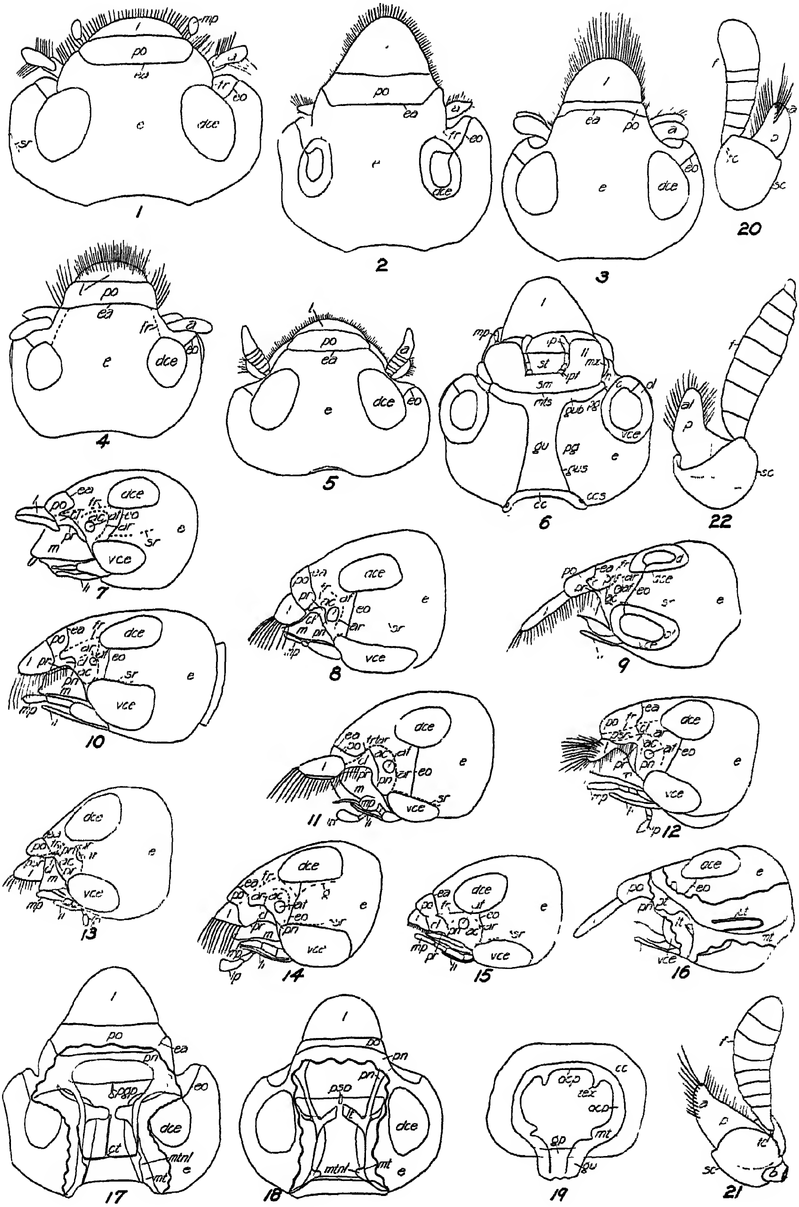


PLATE XXI

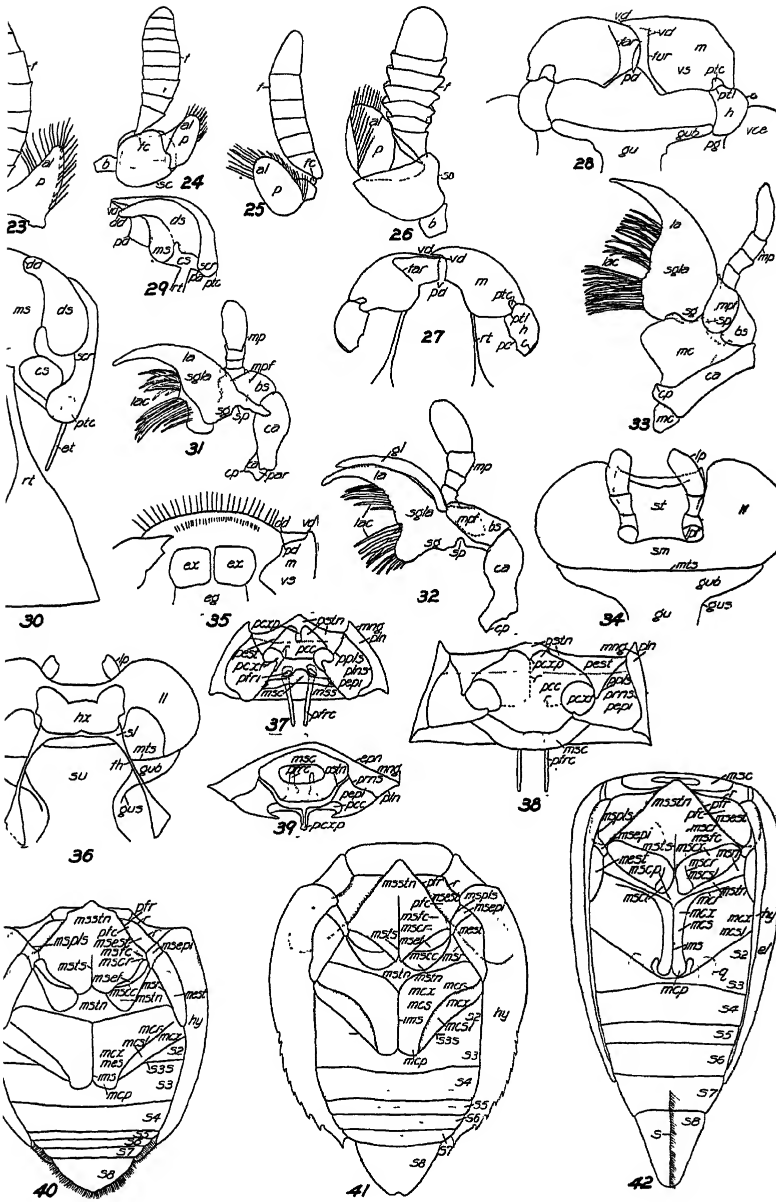


PLATE XXII

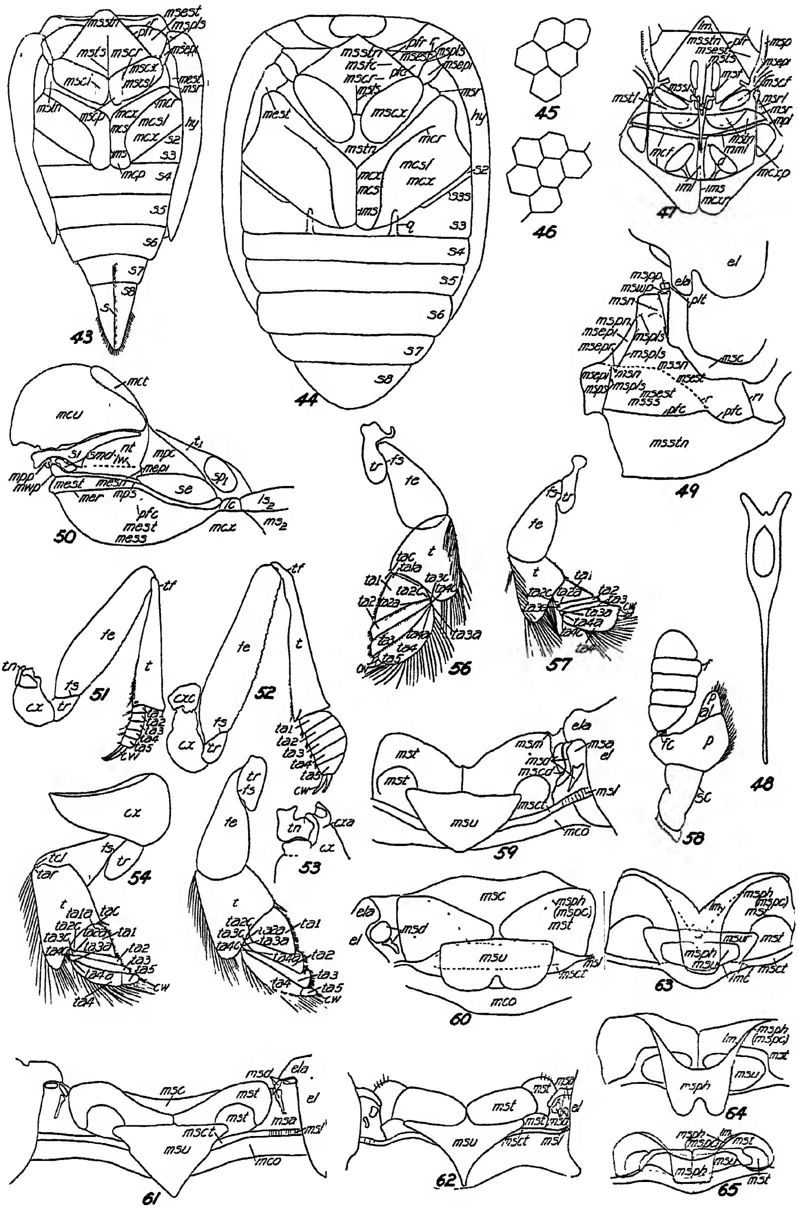


PLATE XXIII

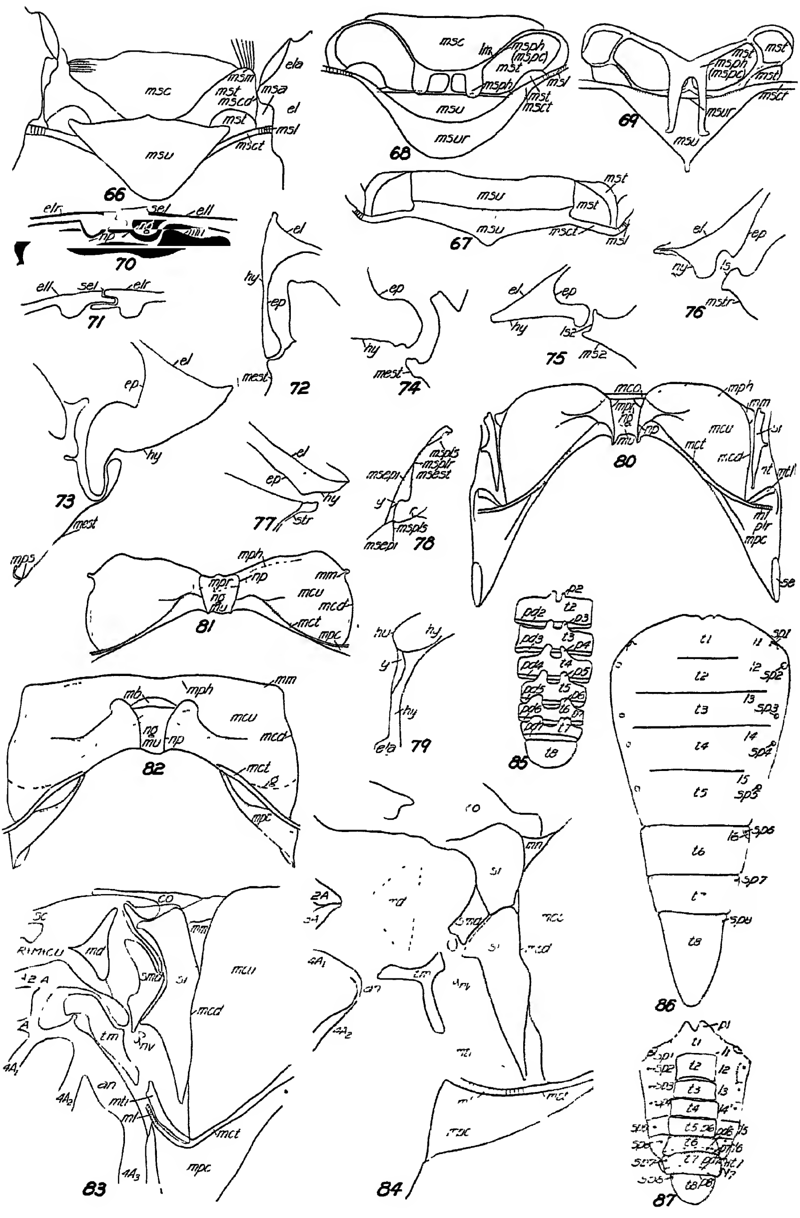
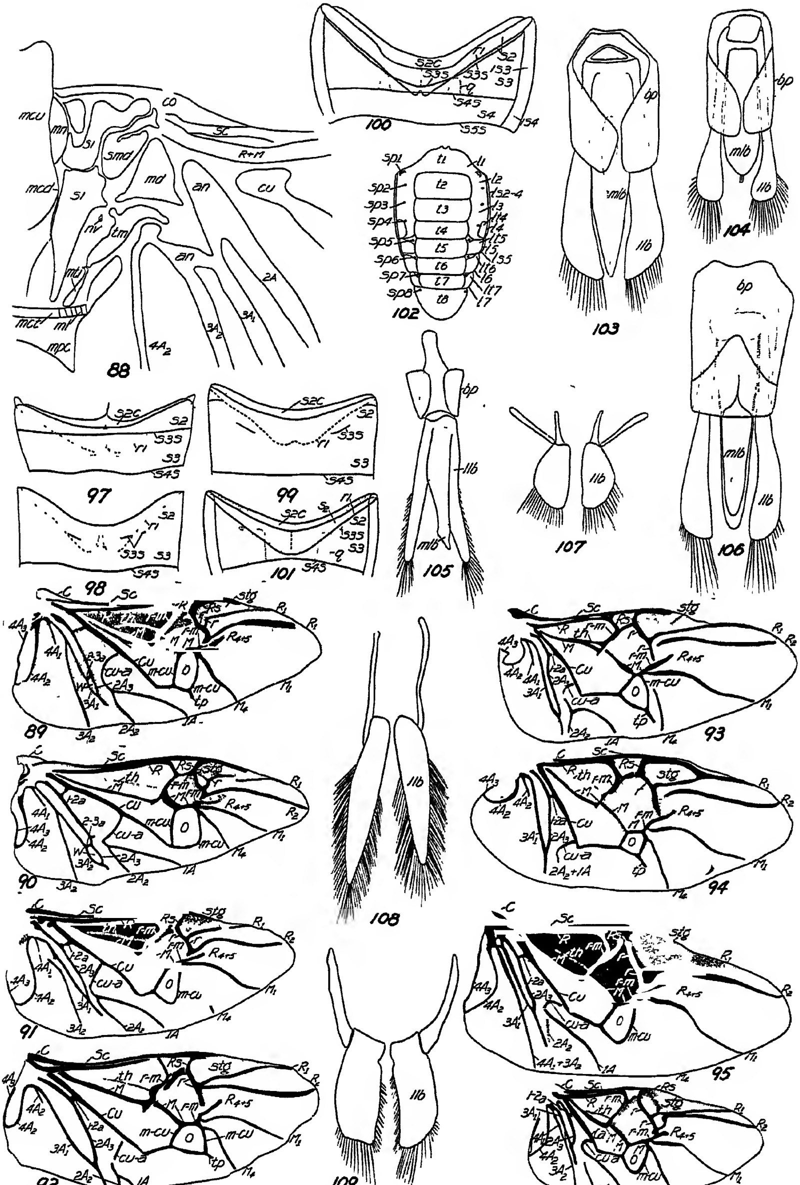


PLATE XXIV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NOTES ON THE BLENNIOID FISHES OF WESTERN NORTH AMERICA

CARL L. HUBBS

THIS paper is presented as a contribution to the systematics of the blennioid fishes of the northeastern Pacific. The following names are introduced for the first time:

Alloclinus, new genus of Clinidae (*holderi*);
Gibbonsia elegans montereyensis, new subspecies;
Gibbonsia metzi, new species;
Anoplarchus purpurescens archolepis, new subspecies;
Lumpenella, new genus of Stichaeidae (*longirostris*);
Epigeichthys, new genus of Stichaeidae (*atro-purpureus*);
Apodichthyinae, new subfamily name (in Pholidae).

In addition to these, the genus Phytichthys, named in Jordan, *Classification of Fishes* (1923), from my manuscript, is here given a diagnosis.

CLINIDAE

ALLOCLINUS, new genus

Type-species. — *Starksia holderi* Lauderbach.

This genus differs from Starksia Jordan and Evermann,[1] to which genus the type-species has been referred, in having the inner teeth in a band in both jaws, the scales and the dorsal spines and soft-rays more numerous and the margin of the dorsal fin elevated instead of depressed between the first and the third spine. Alloclinus differs in a number of structural details from each of the Atlantic genera of the Lepisoma group.[2]

Alloclinus may be diagnosed as follows: Shoulder girdle without upturned hook. Mouth of moderate size, the upper

[1] In Jordan, *Proc. Calif. Acad. Sci.*, (2) 6, 1896, p. 231.
[2] Jordan, *Bull. U. S. Bur. Fish.*, 1902 (1904), p. 544.

jaw nearly half as long as head. Teeth of outer row enlarged in each jaw, each tooth with a broad spatulate tip, evenly rounded when viewed from in front; inner teeth in wide bands, wider above than below, the individual teeth larger in the lower jaw than in the upper, considerably enlarged on the front of the inner edge of the band; vomerine and palatine teeth in narrow bands. A fringed tentacle on anterior nostril; a double filament above each eye, and a triple one at the nape. Scales cycloid, about 50 in lateral line. Outline of spinous portion of dorsal rounded behind the second spine, which is abruptly longer than the third; dorsal with about 25 spines and 11 soft-rays.

(*Alloclinus:* another + *Clinus*)

1. *Alloclinus holderi* (Lauderbach)

Starksia holderi Lauderbach, in Jordan and Starks, Proc. U. S. Nat. Mus., 32, 1907, p. 73, fig. 6.

The description of Alloclinus given above was drawn up from an examination of the type-specimen of *S. holderi.*

AUCHENOPTERUS Günther

Auchenopterus integripinnis (Smith)

Cremnobates integripinnis Smith, Proc. U. S. Nat. Mus., 3, 1880, p. 147; A List of the Fishes of San Diego, California, 1880, no pag.; Jordan and Gilbert, Proc. U. S. Nat. Mus., 3, 1880 (1881), p. 454; Jordan and Jouy, *ibidem*, 4, 1881, p. 4; Jordan and Gilbert, *ibidem*, p. 63 (in part); Bull. U. S. Nat. Mus., 16, 1883, p. 764; Smith, Proc. U. S. Nat. Mus., 6, 1883, p. 216; Jordan, *ibidem*, 7, 1884, p. 142; Smith, *ibidem*, p. 553; West Am. Sci., 1, 1885, p. 45; Jordan, Proc. U. S. Nat. Mus., 8, 1885, p. 390; Rept. U. S. Comm. Fish., 1885, p. 909; Eigenmann, West Am. Sci., 7, 1890, p. 35.

Auchenopterus integripinnis Jenkins and Evermann, Proc. U. S. Nat. Mus., 11, 1889, p. 156; Eigenmann, *ibidem*, 15, 1892, pp. 131, 171, 173; Eigenmann and Eigenmann, Ann. N. Y. Acad. Sci., 6, 1892, p. 357; Jordan and Evermann, Rept. U. S. Comm. Fish., 1895 (1896), p. 469; Bull. U. S. Nat. Mus., 47, pt. 3, 1898, p. 2373; Starks and Morris, Univ. Cal. Publ. Zool., 3, 1907, p. 237; Metz, Ann. Rept. Laguna Mar. Lab., 1, 1911 (1912), p. 53, pl. 3, fig. K; text figs. 22, 23; Fowler, Proc. Acad. Nat. Sci. Phila., 75, 1923, p. 300.

We have collected this species in moderate abundance at the lower tide levels of the reefs of Point Loma and of Bird Rock, San Diego County, California.

GIBBONSIA Cooper

Various authors have accepted as valid either one or two species of this genus. Metz alone has interpreted the forms correctly, but his work is incomplete from a nomenclatorial standpoint. The two species may be readily distinguished by the characters indicated below.

Comparison of the Species of Gibbonsia

Character	*Gibbonsia elegans*	*Gibbonsia metzi*
Vertebrae:	48 to 51	50 to 53
Total number of dorsal and anal rays:	63 to 72 (usually 64 to 70)	69 to 74 (usually 71 or 72)
Dorsal soft-rays:	5 to 8, usually 6 or 7	7 to 9, usually 8 or 9
Outline of soft dorsal:	Usually decidedly angular, and more or less falcate	Usually more rounded
Dorsal soft-rays:	Crowded anteriorly, widely spaced posteriorly	Usually nearly evenly spaced, but occasionally spaced more widely anteriorly
Dorsal base in standard length:	Usually about 1.4	Usually about 1.5
Basal length of anterior crowded dorsal soft-rays in highest ray:	2.3 to 4.3	1.5 to 2.0
Scale rows above posterior end of arch in lateral line:	22 to 28	35 to 40
Average number of transverse scale rows per pore along middle of top of arch in lateral line:	1.6 to 2.2	2.4 to 3.0
Length to caudal base of adult:	Rarely more than 100 mm.; largest seen, 118 mm.	Usually from 100 to 200 mm.; largest seen, 223 mm.
Ocelli:	At least two well developed	Absent or imperfectly developed
Lavender color:	Frequently intense	Never typically developed

Further comparisons of the two species, together with an analysis of the relationships of the two subspecies of *Gibbonsia elegans*, are given in the account of *G. e. montereyensis*.

Gibbonsia elegans elegans (Cooper)

Myxodes elegans Cooper, Proc. Cal. Acad. Sci., 3, 1864, p. 109.

Gibbonsia elegans Jordan and Gilbert, Proc. U. S. Nat. Mus., 3, 1880, p. 25; Smith, *ibidem*, p. 147; A List of the Fishes of San Diego, California, 1880, no pag.; Jordan and Gilbert, Proc. U. S. Nat. Mus., 3, 1880 (1881), p. 454 (in part); Jordan and Jouy, *ibidem*, 4, 1881, p. 4 (in part); Jordan and Gilbert, *ibidem*, p. 63 (in part); Jordan and Evermann, Rept. U. S. Comm. Fish., 1895 (1896), p. 467; Bull. U. S. Nat. Mus., 47, pt. 3, 1898, pp. 2353, 2869; Jordan and McGregor, Rept. U. S. Comm. Fish., 1898 (1899), p. 284; Greeley, Bull. U. S. Fish Comm., 1899, p. 20 (in part); Jordan, Guide to the Study of Fishes, 2, 1905, p. 508; Starks and Morris, Univ. Cal. Publ. Zool., 3, 1907, p. 232 (in part); Evermann and Latimer, Proc. Biol. Soc. Wash., 23, 1910, p. 139; Metz, Ann. Rept. Laguna Mar. Lab., 1, 1911 (1912), p. 45 (southern specimens only); Osburn and Nichols, Bull. Am. Mus. Nat. Hist., 35, 1916, p. 178; Bean and Weed, Trans. Roy. Soc. Canada, (3) 13, 1919 (1920), pp. 80, 81; Fowler, Proc. Acad. Nat. Sci. Phila., 75, 1923, pp. 293 (in part), 300.

Clinus evides Jordan and Gilbert, Bull. U. S. Nat. Mus., 16, 1883, pp. 763, 962 (name and synonymy only); Smith, Proc. U. S. Nat. Mus., 6, 1883, p. 235 (in part); West Am. Sci., 1, 1885, p. 45 (in part); Jordan, Rept. U. S. Comm. Fish., 1885, p. 909 (in part); Eigenmann, West Am. Sci., 7, 1890, p. 35; Proc. U. S. Nat. Mus., 15, 1892, pp. 171, 173 (in part); Eigenmann and Eigenmann, Ann. N. Y. Acad. Sci., 6, 1892, p. 357 (in part).

Gibbonsia elegans evides Jordan and Evermann, Bull. U. S. Nat. Mus., 47, pt. 4, 1900, fig. 815.

Gibbonsia evides Jordan, Guide to the Study of Fishes, 2, 1905, fig. 448.

Clinus ocellifer Mocquard, Bull. Soc. Philom. Paris, 1886, p. 44.

Gibbonsia elegans montereyensis, new subspecies

Gibbonsia elegans Greeley, Bull. U. S. Fish Comm., 1899, p. 20 (in part); Starks and Morris, Univ. Cal. Publ. Zool., 3, 1907, p. 232 (in part); Metz, Ann. Rept. Laguna Mar. Lab., 1, 1911 (1912), p. 45 (northern specimens), and probably of other authors (in part); Bean and Weed, Trans. Roy. Soc. Canada, (3) 13, 1919 (1920), pp. 81–82 (material from Ucluelet, British Columbia; one specimen examined, and designated a paratype).

Gibbonsia evides Starks and Morris, *l. c.*, p. 235 (in part), and probably of other authors (in part).

This well-marked form has been confused by authors in general with either *G. elegans* or *G. evides* (= *G. metzi*), or with

both of these species. Metz alone has distinguished it from other forms of the genus, but applied no name to it, regarding it merely as a race of *elegans*. Being well differentiated from that form, however, and being characteristic of the Monterey fauna, it may be called *montereyensis*.

Comparison of *Gibbonsia elegans montereyensis* with the Two Other Forms of the Genus

Character	*G. e. elegans*	*G. e. montereyensis*	*G metzi*
Vertebrae:	48 or 49	49 to 51	50 to 53
Scale rows above posterior end of arch in lateral line:	22 to 26	24 to 28	35 to 40
Total number of dorsal and anal rays:	63 to 67, usually 64 to 66	65 to 72, usually 68 to 70	69 to 74, usually 71 or 72
Dorsal spines:	32 to 34	34 to 36	34 to 37
Anal soft-rays:	21 to 24, usually 23	23 to 28, usually 25 or 26	24 to 27, usually 26
Dorsal soft-rays:*	5 to 8, usually 6 or 7	5 to 8, usually 6 or 7	7 to 9, usually 8 or 9
Basal length of anterior crowded dorsal soft rays in highest ray:	4.3 to 2.5	3.6 to 2.3	2.0 to 1.5
Highest dorsal soft-ray:†	12.0 to 13.5	10.5 to 14.0	9.5 to 12.5
Highest anal ray:	10.5 to 12.5	9.5 to 11.5	8.5 to 11.0
Depth of body:	22.0 to 26.0	21.0 to 24.5	20.0 to 24.0
Length of head:	22.5 to 27.0	22.0 to 25.0	22.0 to 26.0
Length of orbit:	5.0 to 6.5	4.5 to 6.0	4.0 to 5.5

* The number of dorsal soft-rays is apparently identical in the two subspecies of *Gibbonsia elegans*, the numbers 6 and 7 occurring in each form with about equal frequency.

† These and the following measurements are expressed in hundredths of the length to caudal base.

Although *montereyensis* can be separated readily from *elegans*, it obviously has more in common with that form than with *metzi* (*cf.* comparison of the species under the heading of the genus). Throughout the wide range of variation in coloration, for example, the two forms are the exact counterparts of one another. In most respects, however, including all of the variable segmental characters (number of vertebrae, fin-rays and scales), *montereyensis* definitely approaches, and in some cases almost corresponds with *metzi*, as indicated in the preceding comparison.

Although it is frequently found in the same tide-pools with *Gibbonsia metzi*, no evidence was secured to indicate that it ever hybridizes with that form. It does intergrade, however, with *G. e. elegans*, the blending taking place along the outer or ocean coast of Santa Barbara County. In view of the most important distinctive features of the two subspecies, namely, the number of fin-rays, the intergradation may be expressed in the following form.

TABLES DEMONSTRATING THE INTERGRADATION OF THE TWO SUBSPECIES OF *GIBBONSIA ELEGANS*

FORM AND LOCALITY	*Total number of dorsal and anal rays*									
	63	64	65	66	67	68	69	70	71	72
Gibbonsia elegans montereyensis: California south to and including San Luis Obispo County:*	—	—	1	2	10	48	63	31	11	2
Intergrades: Near Pt. Sal and Pt. Arguello:	—	—	—	2	1	1	1	1	1	—
Intergrades: Near Pt. Conception:	—	3	2	4	2	1	—	—	—	—
Gibbonsia elegans elegans: South of Pt. Conception region:	9	41	52	25	2	—	—	—	—	—

* Including one specimen from British Columbia with 69 rays.

TABLES DEMONSTRATING THE INTERGRADATION OF THE TWO SUBSPECIES OF *GIBBONSIA ELEGANS* (*Continued*)

FORM AND LOCALITY	*Number of anal soft rays*							
	21	22	23	24	25	26	27	28
Gibbonsia elegans montereyensis:								
California south to and including San Luis Obispo County:†	—	—	1	3	64	84	11	1
Intergrades:								
Near Pt. Sal and Pt. Arguello:	—	—	—	2	2	2	1	—
Intergrades:								
Near Pt. Conception:	—	—	5	6	1	—	—	—
Gibbonsia elegans elegans:								
South of Pt. Conception region:	1	9	90	29	—	—	—	—

† Including one specimen from British Columbia with 26 rays.

FORM AND LOCALITY	*Number of dorsal spines*				
	32	33	34	35	36
Gibbonsia elegans montereyensis:					
California south to and including San Luis Obispo County:‡	—	—	44	112	14
Intergrades:					
Near Pt. Sal and Pt. Arguello:	—	—	3	4	—
Intergrades:					
Near Pt. Conception:	—	6	6	—	—
Gibbonsia elegans elegans:					
South of Pt. Conception region:	8	98	23	—	—

‡ Including one from British Columbia with 35 spines.

Gibbonsia e. montereyensis differs from *Gibbonsia e. elegans* in such characters as very frequently distinguish the northern race or species of a geminate pair from its more southern relative. The most plausible explanation of the facts is that a portion of the population of the *elegans*-like common ancestor of the two forms, having moved northward, has become modified into a

distinct form, *montereyensis*. Now the lesser similarity between the species *metzi* and *elegans*, and the absence of intergradation between the two, suggest that these two forms, had already become separated prior to the differentiation of *montereyensis*. Probably the immediate ancestor of *metzi* was then the northern representative of the immediate ancestor of *elegans*, because the distinctive features of *metzi* other than those of coloration, all more or less directly determined by the increased number of myotomes, are like those developed in many other colder water representatives of warmer water forms. If this supposition be true, then the subspecies *montereyensis* is approaching *metzi*, because the two, although at different times, have been independently differentiated from a similar ancestor in response to similar environmental conditions. At least the facts seem to indicate that the similarity between *montereyensis* and *metzi* is not a measure of their consanguinity.

Description of the holotype, Cat. No. 55003, Museum of Zoölogy, University of Michigan, a specimen 83 mm. long to the caudal base, collected in May or June, 1915, by the writer in a tidal rock-pool on a reef at Pacific Grove, near Monterey, California. — The body is rather slender and strongly compressed; greatest depth contained 4.6 times in standard length; least depth of the caudal peduncle, 4.8 times in head; greatest width of trunk, two-fifths the greatest depth; width at middle of urosome, one-fourth the depth at the same point. The dorsal profile from its highest point above the middle of the trunk slopes rather abruptly forward in an even curve to the tip of the snout, which lies in the horizontal passing through the lower margin of the orbit. The dorsal and ventral contours gradually converge backward to the front of the soft dorsal fin and the corresponding lobe of the anal fin, then rather rapidly converge to the slender caudal peduncle. The length of the head and trunk is two-fifths of the total standard length (often longer in paratypes); the anus is located almost immediately in advance of the origin of the anal fin.

The rostral angle is about 75 degrees; the mouth is terminal; the jaws are equal; the maxillary extends backward to below

middle of pupil; the round orbits are separated by a slightly convex interorbital; the fringed supraorbital flap is as long as the pupil; the nostril opens at the apex of a short tube, the posterior rim of which is elevated in the form of a flap nearly as long as the pupil; the preopercle is broadly rounded; both the bony and membranous opercular margins are gently concave above the angle; a conspicuous rounded membranous fold connects the upper end of the branchial aperture and the upper end of the pectoral base; the inner edge of the pectoral girdle is provided with a conspicuous upturned hook. The bluntly conic teeth are moderately enlarged in an even outer row in each jaw, behind which there is a narrow crescent-shaped band of premaxillary teeth, and a single series of mandibular teeth. Length of head, including opercular membrane, 4.5 in standard length; snout 4.3 in head; orbit 4.35 in head; interorbital width 1.7 in orbit; upper jaw 3.0 in head; width of head half its length.

The lateral line is elevated anteriorly to form a straight-topped arch, the chord of which is slightly more than one-third its total length. It is conspicuous anteriorly, becoming obsolescent toward the caudal. The scales are small, there being about 28 irregular rows above the end of the arch. Each scale is marked in all fields by concentric circuli and fine radii; the focus is central or basal.

The base of the spinous dorsal is contained 1.4 times in the length to caudal; all the spines are tipped with membranous filaments; the first five spines are graduated from the first and highest to the fifth, which is shorter than the sixth; all these are more widely spaced than those following, and the first three are rather distinctly set off from the fourth and fifth; the remaining spines (there are XXXIV in all) are subequal, slightly increasing in height toward the posterior end of the fin. The dorsal soft-rays form a very distinct and angulated lobe, the posterior edge of which is slightly falcate; the first four rays are closely approximated, the following three (the last regarded as doubled) widely spaced. The first of the two anal spines is slightly the shorter; the 25 anal soft-rays slightly decrease in height toward the middle of the fin, then increase posteriorly to form a lobe

approaching in form that of the soft dorsal. The rounded caudal fin contains 12 (11 to 13) principal rays; pectoral, 13 rays; pelvic, I, 3.

The coloration of the type is of the barred phase, with sharply marked ocelli. In life the color was chiefly lavender.

The many paratypes, deposited in several museums, were collected at numerous localities in northern and central California. As already indicated, this subspecies intergrades with *G. e. elegans* along the outer coast of Santa Barbara County.

Gibbonsia metzi, new species

Blakea elegans Steindachner, Sitz. Akad. Wiss. Wien., 74, 1876 (1877), p. 148 (Ichth. Beitr., 5, 1876, p. 148) (exclusive of synonymy).

Gibbonsia elegans Jordan and Gilbert, Proc. U. S. Nat. Mus., 3, 1880 (1881), p. 454 (in part); Jordan and Jouy, *ibidem*, 4, 1881, p. 4 (in part); Jordan and Gilbert, *ibidem*, p. 53 (in part); Greeley, Bull. U. S. Fish Comm., 1899, p. 20 (in part).

Clinus evides Jordan and Gilbert, Bull. U. S. Nat. Mus., 16, 1883, pp. 763, 962 (description only); Smith, Proc. U. S. Nat. Mus., 6, 1883, p. 235 (in part); West Am. Sci., 1, 1885, p. 45 (in part); Jordan, Rept. U. S. Comm. Fish., 1885, p. 909 (in part); Eigenmann, Proc. U. S. Nat. Mus., 15, 1892, pp. 171, 173 (in part); Eigenmann and Eigenmann, Ann. N. Y. Acad. Sci., 6, 1892, p. 357 (in part).

Gibbonsia evides Jordan and Evermann, Rept. U. S. Comm. Fish., 1895 (1896), p. 467; Bull. U. S. Nat. Mus., 47, pt. 3, 1898, pp. 2352, 2869; Starks and Morris, Univ. Cal. Publ. Zool., 3, 1907, p. 235 (in part); Metz, Ann. Rept. Laguna Mar. Lab., 1, 1911 (1912), pp. 43, 45–52; Bean and Weed, Trans. Roy. Soc. Canada, (3) 13, 1919 (1920), pp. 81–82; (?)Fowler, Proc. Acad. Nat. Sci. Phila., 72, 1920 (1921), p. 402.

This species was first distinguished from *Gibbonsia elegans* in 1896 and 1898, by Jordan and Evermann. In the following year (1899) Greeley, obviously confused by the fact that *elegans* in the northern half of its range is represented by a subspecies, then unnamed, which agrees with the present form in certain characters, reunited the species. Jordan and Evermann then erroneously regarded the two as subspecies. Starks and Morris recognized the distinctness of this species from *G. elegans*, but included in their concept of *G. "evides"* the northern subspecies of *elegans*. It remained for Metz to distinguish clearly between

these three forms. Bean and Weed recognized two forms, those here named *G. e. montereyensis* and *G. metzi.*

The authors who have distinguished between the present species and *G. elegans* have used for it the apparently inapplicable name *Gibbonsia evides.* When distinguishing this species as valid in 1898, Jordan and Evermann mention that "the name *evides* may apparently be retained for this species, as the description of Jordan and Gilbert is based entirely upon Monterey specimens of this species," not of *G. e. montereyensis.* It was intended, however, as a substitute for the name *elegans*, already used in the genus Clinus, to which the species were then referred. As this stand did not appear to agree with current nomenclatorial practice, the writer submitted the case to Dr. Leonhard Stejneger, who kindly gave it his attention and presented his private opinion on the subject in a letter dated February 7, 1916, in the following words: "Jordan and Gilbert wrote '*C. evides* J. & G. nom [en] sp [ecificum] nov [um]' and '(*Myxodes* (*Gibbonsia*) *elegans* Cooper not *Clinus elegans* C. & V.).' They did not write *Clinus evides* species nova. The name is clearly given as a substitute without reference to any type-specimen. As such it takes the status of Cooper's *elegans*, and whatever the type of the latter may be, it stands and falls with the latter. If *elegans* is not a *Clinus*, it regains validity, and *evides* becomes an unconditional synonym." Such being the case, the species incorrectly named *evides* by authors is given a new name, *Gibbonsia metzi.* This specific name is chosen as a compliment to Charles W. Metz, now a well-known geneticist, the first to differentiate clearly between the three forms of the genus.

As mentioned in the account of *G. e. montereyensis, G. metzi* rather closely resembles *G. elegans,* especially the Monterey subspecies. Resemblance in this case, however, is not to be construed as indicative of close relationship, for *G. e. montereyensis* probably has been derived from the *elegans*-like common ancestor of the two subspecies, whereas *elegans* and *metzi* presumably had become differentiated at a prior time. *G. metzi* certainly does not intergrade with *G. elegans,* and probably does not even sporadically hybridize with it, as no specimen was

examined which could not accurately be referred to one or the other of the species. Of the three forms of Gibbonsia, *metzi* most closely approaches Heterostichus, not only in structure, but also in ecological distribution.

Description of the holotype, Cat. No. 55004, Museum of Zoölogy, University of Michigan, a specimen 145 mm. long to the caudal fin, collected by the writer in May or June, 1915, at Pacific Grove, Monterey County, California, among plants in a tidal pool on the reef. — General form as in *Gibbonsia elegans montereyensis;* greatest depth of body, 4.5 in standard length; least depth of caudal peduncle, 4.0 in head; greatest width of trunk, 2.3 in depth; width at middle of urosome, 4.0 in the depth at that point (in many paratypes, especially in smaller ones, the body is more slender throughout).

Rostral angle a little greater than 75 degrees (usually less, as low as 60 degrees in some paratypes); mouth terminal; lower jaw slightly projecting (the jaws usually equal); maxillary subtending the anterior half of the eye; orbit, interorbital, nasal flap, opercles, shoulder girdle and dentition as in *Gibbonsia elegans montereyensis.* Length of head 4.2 in standard length (usually shorter); snout 4.35 in head; orbit 5.65 (frequently larger); interorbital nearly as wide as orbit (less than two-thirds as wide in some specimens); upper jaw 3.2; head half as wide as long.

The lateral line follows the same course that it does in *elegans:* anteriorly it is horizontal and nearly straight, then rather abruptly oblique to above the anus, and again horizontal along the tail, a little below the midline; the chord of the arch is half the length of this posterior straight portion of the lateral line. The scales are very small, there being about 38 rows above the end of the anterior arch in the lateral line. Approximately as in *G. elegans*, there are 23 contiguous plates from which the pores open obliquely either upward or downward along the anterior straight portion of the lateral line; 15 pores with narrower plates becoming obsolete posteriorly along the oblique portion of the lateral line, and 35 separated pairs of pores (one opening at each end of a short tube) along the tail.

The base of the spinous dorsal is contained 1.5 times in the standard length of the body; all the spines bear short terminal filaments; the first dorsal spine is the highest of the first five, which are graduated in length, and separated more widely than those which follow; the first three are rather distinctly set off from the next two; the following spines are equal in length, except the last few, which are slightly higher than the rest. The nine dorsal soft-rays (the last doubled) form an evenly rounded lobe nearly twice as high as the dorsal spines; the posterior soft-rays are only slightly more widely spaced than the anterior ones. The first anal spine is lower than the second, which is shorter than the soft-rays; the lowest of the 26 anal soft-rays are the median ones; the highest, the posterior ones, which are similar to the dorsal soft-rays. The caudal fin is rounded, and is composed of 12 (or 13) principal rays; pectoral, 13; pelvic, I, 3.

The color in life was brown; the pattern, variegated, with interrupted traces of lengthwise streaks.

In a single specimen, as also very rarely in *montereyensis*, a dorsal soft-ray is simply branched; in another, otherwise normal, the penultimate dorsal spine is bifid at its tip, and the last one is widely forked; as usual in fishes, perhaps as the result of injury, one or a few rays often lie free in the interradial membranes.

The very numerous paratypes of this species, deposited in several museums, were collected along the entire length of the California coast, chiefly in tide-pools on the rocky reefs.

HETEROSTICHUS Girard

This genus, containing a single large species, was probably derived from Gibbonsia, being distinguished from that genus by several characters which in this family may be regarded as specialized, namely the sharp snout, projecting mandible and produced caudal lobes.

Heterostichus rostratus Girard

Heterostichus rostratus Girard, Proc. Acad. Nat. Sci. Phila., 7, 1854, p. 143; U. S. Pac. R. R. Surv., 10, pt. 4, 1858, p. 26, pl. 13; Günther, Cat. Fishes Brit. Mus., 2, 1860, p. 264; 3, 1861, p. 261; Yarrow and Henshaw,

Ann. Rept. U. S. Geog. Surv. West 100th Mer., 1878, pp. 201, 202; Jordan and Gilbert, Proc. U. S. Nat. Mus., 3, 1880, p. 25; Smith, A List of the Fishes of San Diego, California, 1880, no pag.; Jordan and Gilbert, Proc. U. S. Nat. Mus., 3, 1880 (1881), p. 454; Jordan and Jouy, *ibidem*, 4, 1881, p. 5; Jordan and Gilbert, *ibidem*, p. 63; 4, 1881 (1882), p. 279; Bull. U. S. Nat. Mus., 16, 1883, pp. 764, 962; Smith, Proc. U. S. Nat. Mus., 6, 1883, p. 217; West Am. Sci., 1, 1885, p. 46; Jordan, Rept. U. S. Comm. Fish., 1885, p. 909; Eigenmann, Proc. U. S. Nat. Mus., 15, 1892, pp. 171, 173 (one reference on p. 131 to "*Heterostichnus rostratus*" probably does not belong to this species); Eigenmann and Eigenmann, Ann. N. Y. Acad. Sci., 6, 1892, p. 357; Jordan and Evermann, Rept. U. S. Comm. Fish., 1895 (1896), p. 467; Bull. U. S. Nat. Mus., 47, pt. 3, 1898, p. 2351; Jordan and McGregor, Rept. U. S. Comm. Fish., 1898 (1899), p. 284; Jordan, Guide to the Study of Fishes, 2, 1905, p. 507; Starks and Morris, Univ. Cal. Publ. Zool., 3, 1907, p. 232; Holder, Am. Nat., 41, 1907, p. 587, fig.; Holder and Jordan, Fish Stories (Holt & Co.) 1909, chap. 29; Holder, Bull. U. S. Fish Comm., 28, 1908 (1910), p. 1140; Evermann and Latimer, Proc. Biol. Soc. Wash., 23, 1910, p. 139; Metz, Ann. Rept. Laguna Mar. Lab., 1, 1911 (1912), p. 43, pl. 2, fig. G; text figs. 13, 14; Halkett, Check List Fishes Canada, 1913, p. 110; Ann. Rept. Dept. Mar. Fish. Canada, 47, 1914, p. 365; Starks, The Sesamoid Articular (Stanford Univ. Publ., Biol. Ser.), 1916, p. 35; Jordan, The Genera of Fishes, pt. 2, 1919, p. 258; Hubbs, Copeia, No. 80, 1920, p. 19; Fowler, Proc. Acad. Nat. Sci. Phila., 75, 1923, pp. 293 and 300; Copeia, No. 120, 1923, p. 79.

CRYPTOTREMA Gilbert

Cryptotrema corallinum Gilbert

Cryptotrema corallinum Gilbert, Proc. U. S. Nat. Mus., 13, 1890, p. 101; Jordan and Evermann, Bull. U. S. Nat. Mus., 47, pt. 3, 1898, p. 2366; Hubbs, Univ. Calif. Publ. Zool., 16, 1916, p. 165; Fowler, Proc. Acad. Nat. Sci. Phila., 75, 1923, pp. 294 and 300.

A specimen of this species 35 mm. long to caudal, was taken by the California State Fisheries Laboratory staff in a young fish trawl, over deep water 30 miles E. by N. of Bishop Rock off the coast of southern California. This record would seem to indicate that the half-grown of this blenny are pelagic.

NEOCLINUS Girard

Neoclinus blanchardi Girard

Neoclinus blanchardi Girard, U. S. Pac. R. R. Surv., 10, pt. 4, 1858, p. 114; Jordan and Gilbert, Proc. U. S. Nat. Mus., 4, 1881, p. 63; Jordan and Evermann, Bull. U. S. Nat. Mus., 47, pt. 3, 1898, p. 2354; Starks and Morris, Univ. Calif. Publ. Zool., 3, 1907, p. 236; Snyder, Proc. U. S. Nat. Mus., 44, 1913, p. 459.

PTEROGNATHUS Girard

This genus differs markedly from Neoclinus, with which however it is very closely related, in having the head filament not greatly enlarged in the adult male; the maxillary inordinately elongate, reaching past the gill-opening (in Neoclinus the maxillary is also greatly elongated, but does not reach to the gill-opening); the maxillary pocket much larger, extending to the tip of the bone. *Pterognathus satiricus* is further distinguished from *Neoclinus blanchardi* in the development of two ocelli on the dorsal fin, rather than one.

Pterognathus satiricus (Girard)

Neoclinus satiricus Girard, Proc. Acad. Nat. Sci. Phila., 1859, p. 57; Jordan and Evermann, Bull. U. S. Nat. Mus., 47, pt. 3, 1898, p. 2355; Snyder, Proc. U. S. Nat. Mus., 44, 1913, p. 459.

BLENNIIDAE

SCARTELLA Jordan

Scartella Jordan, Proc. U. S. Nat. Mus., 9, 1886, p. 50; Jordan and Evermann, Bull. U. S. Nat. Mus., 47, pt. 3, 1898, p. 2384.

Blenniolus Jordan and Evermann, *ibidem*, p. 2386.

Although proposed as a subgenus of Hypsoblennius, Blenniolus proves to be a synonym of Scartella, the type-species, *Blennius brevipinnis* Günther, having the gill-membranes united and free from the isthmus, and the other essential characters as in that genus.

Scartella brevipinnis (Günther)

Blennius brevipinnis Günther, Cat. Fishes Brit. Mus., 3, 1861, p. 226.

Hypsoblennius brevipinnis Jordan and Evermann, Bull. U. S. Nat. Mus., 47, pt. 3, 1898, p. 2390.

This species seems to be the Pacific representative of *Scartella microstoma* Poey.

HYPSOBLENNIUS Gill

Hypsoblennius gilberti (Jordan)

Hypleurochilus gentilis Jordan and Gilbert, Proc. U. S. Nat. Mus., 3, 1880, p. 25; Smith, *ibidem*, p. 147; Jordan and Gilbert, *ibidem*, 3, 1880 (1881), p. 454; Jordan and Jouy, *ibidem*, 4, 1881, p. 5; Jordan and Gilbert, *ibidem*, p. 63. (Not *Blennius gentilis* Girard.)

Isesthes gentilis Jordan and Gilbert, Bull. U. S. Nat. Mus., 16, 1883, p. 757 (in part).

Hypsoblennius gentilis Fowler, Proc. Acad. Nat. Sci. Phila., 75, 1923, p. 294 (in part).

Isesthes gilberti Jordan, Proc. U. S. Nat. Mus., 5, 1882, p. 349; Jordan and Gilbert, Bull. U. S. Nat. Mus., 16, 1883, p. 959; Smith, Proc. U. S. Nat. Mus., 6, 1883, p. 235; West Am. Sci., 1, 1885, p. 45; Eigenmann and Eigenmann, *ibidem*, 6, 1889, p. 44; Ann. N. Y. Acad. Sci., 6, 1892, p. 357; Eigenmann, Proc. U. S. Nat. Mus., 1892, pp. 126, 131, 171, pl. 17, figs. 16–20.

Hypsoblennius gilberti Jordan, Rept. U. S. Comm. Fish and Fish., 1885, p. 907; Evermann and Jenkins, Proc. U. S. Nat. Mus., 14, 1891, p. 163; Jordan and Evermann, Rept. U. S. Comm. Fish and Fish., 1895 (1896), p. 470; Bull. U. S. Nat. Mus., 47, pt. 3, 1898, p. 2386; Starks and Morris, Univ. Calif. Publ. Zool., 3, 1907, p. 238; Metz, Ann. Rept. Laguna Mar. Lab., 1, 1911 (1912), p. 56 (generic name misprinted Hyposoblennius), pl. 2, fig. F; Fowler, Proc. Acad. Nat. Sci. Phila., 75, 1923, p. 300.

?*Hypsoblennius striatus* Fowler, *ibidem*, 1923, p. 294.

Hypsoblennius gentilis (Girard)

Blennius gentilis Girard, Proc. Acad. Nat. Sci. Phila., 7, 1854, p. 149; U. S. Pac. R. R. Surv., 10, pt. 4, 1858, p. 113, pl. 25a, fig. 4; Günther, Cat. Fishes Brit. Mus., 3, 1861, p. 217.

Hypleurochilus gentilis Gill, Proc. Acad. Nat. Sci. Phila., 1861, p. 168; Lockington, *ibidem*, 1881, p. 13.

Isesthes gentilis Steindachner, Sitz. Acad. Wiss. Wien, 74, 1876 (1877), p. 150 (Ichth. Beit., 5, 1876, p. 150); Jordan, Proc. U. S. Nat. Mus., 5, 1882, p. 349; Jordan and Gilbert, *ibidem*, p. 369; Bull. U. S. Nat. Mus., 16, 1883, pp. 757 (in part), 959; Smith, West Am. Sci., 1, 1885, p. 46; Eigenmann, Proc. U. S. Nat. Mus., 15, 1892, pp. 126, 131, 171; Eigenmann and Eigenmann, Ann. N. Y. Acad. Sci., 6, 1892, p. 357.

Hypsoblennius gentilis Jordan, Proc. U. S. Nat. Mus., 8, 1885, p. 389; Rept. U. S. Comm. Fish., 1885, p. 907; Jordan and Evermann, *ibidem*, 1895 (1896), p. 470; Bull. U. S. Nat. Mus., 47, pt. 3, 1898, p. 2387; Rutter, Proc. Cal. Acad. Sci., (3) 3, 1904, p. 253; Starks and Morris, Univ. Cal. Publ. Zool., 3, 1907, p. 238; Metz, Ann. Rept. Laguna Mar. Lab., 1, 1911 (1912),

p. 56, pl. 3, figs. E, G, text figs. 26, 27; Hubbs, Univ. Cal. Publ. Zool., 16, 1916, p. 165; Osburn and Nichols, Bull. Am. Mus. Nat. Hist., 35, 1916, p. 178; Fowler, Proc. Acad. Nat. Sci. Phila., 75, 1923, p. 294 (in part), 300; Copeia, no. 120, 1923, p. 79.

Hypsoblennius gentilis ranges from Monterey Bay, California, southward along the coast of southern California, and along both coasts of Lower California,[3] having a more extensive range than *H. gilberti*. It is most abundant southward, a fact in keeping with the tropical affinities of the species.

Unlike *H. gilberti*, which is characteristic of the reef association, *H. gentilis* is essentially a fish of the bays, only occasionally entering the intertidal zone of the reefs.

Hypsoblennius jenkinsi (Jordan and Evermann)

Hypsoblennius striatus Evermann and Jenkins, Proc. U. S. Nat. Mus., 14, 1891, p. 163 (not of Steindachner).

Chasmodes jenkinsi Jordan and Evermann, in Jordan, Proc. Calif. Acad. Sci., (2) 6, 1896, p. 232, pl. 39; Bull. U. S. Nat. Mus., 47, pt. 3, 1898, p. 2391.

We have examined material of this species collected by Edmund Heller at San Filipe Bay, on the Gulf of California.

RUNULA Jordan and Bollman

Contrary to the statement in the original description of this genus, the lower jaw is provided with a pair of immense curved tusk-like canines, more than half as long as the eye. The genus obviously is a member of the Petroskirtes group of the Indo-Pacific fauna, but may apparently stand as distinct.

Runula azalea Jordan and Bollman

Runula azalea Jordan and Bollman, Proc. U. S. Nat. Mus., 12, 1889 (1890), p. 171; Jordan, Proc. Calif. Acad. Sci., (2) 6, 1896, p. 233, pl. 37; Jordan and Evermann, Bull. U. S. Nat. Mus., 47, pt. 3, 1898, p. 2377; Osburn and Nichols, Bull. Am. Mus. Nat. Hist., 35, 1916, p. 178; Nichols, Zoologica, 5, 1924, p. 65.

We have examined a specimen of this species, 36 mm. long

[3] Four specimens, representing both sexes, were collected by Mr. Edmund Heller at San Filipe Bay, Lower California.

to caudal fin, collected by the *Albatross* at surface station 18, off Ecuador, March 3, 1888. Dorsal rays, 42; anal, 29.

The young and half-grown of this species are probably pelagic in habitat, as our record and that of Osburn and Nichols indicate. This condition would help to explain the occurrence of a representative of this Indo-Pacific group in the Panamaic fauna.

It is not improbable that *Atopoclinus ringens* Vaillant [4] and *Runula albolinea* Nichols [5] may prove identical with this species.

STICHAEIDAE

CEBIDICHTHYS Ayres

This generic name has usually been misspelled Cebedichthys; it was originally given in the proper form, Cebidichthys.

Cebidichthys violaceus (Girard)

Apodichthys violaceus Girard, Proc. Acad. Nat. Sci. Phila., 7, 1854, p. 150.

Cebidichthys violaceus Girard, U. S. Pac. R. R. Surv., 6, pt. 4, 1857, p. 20; 10, pt. 4, 1858, p. 121, pl. 25b, figs. 4, 5; Suckley, *ibidem*, book 2, 1860, p. 355, pl. 25b, figs. 4, 5; Günther, Cat. Fishes Brit. Mus., 3, 1861, p. 260; Gill, Proc. Acad. Nat. Sci. Phila., 1862, p. 279; Jordan, The Genera of Fishes, pt. 2, 1919, p. 262.

Cebedichthys violaceus Jordan and Gilbert, Proc. U. S. Nat. Mus., 3, 1880 (1881), p. 454; Jordan and Jouy, *ibidem*, 4, 1881, p. 4; Bull. U. S. Nat. Mus., 16, 1883, pp. 774, 962; Eigenmann and Eigenmann, Proc. U. S. Nat. Mus., 11, 1888 (1889), p. 465; Ann. N. Y. Acad. Sci., 6, 1892, p. 357; Gilbert, Rept. U. S. Comm. Fish., 1893 (1896), p. 470; Jordan and Evermann, *ibidem*, 1895 (1896), p. 475; Bull. U. S. Nat. Mus., 47, pt. 3, 1898, p. 2427; Jordan, Guide to the Study of Fishes, 2, 1905, p. 512; Starks, The Sesamoid Articular (Stanford Univ. Publ., Biol. Ser.), 1916, p. 35.

Cebidichthys crista-galli Ayres, Proc. Cal. Acad. Sci., 1, 1855, p. 58, pl. 1, figs. 1–3 (not *Centronotus crista galli* Günther).

Anoplarchus alectrolophus Jordan and Evermann, Bull. U. S. Nat. Mus., 47, pt. 3, 1898, pp. 2422, 2869 (not of Pallas).

We have taken this species at numerous localities from Crescent City to Carpenteria, California.

The rostral and occipital crests are inconspicuous in the young,

[4] *Bull. Soc. Philom.*, Paris, (8) 5, 1893, p. 73.
[5] *Zoologica*, 5, 1924, p. 64, fig. 11.

but become elevated in the adult, particularly in the breeding male. The female has but one ovary.

TABLE OF PROPORTIONAL MEASUREMENTS OF ADULTS OF *CEBIDICHTHYS VIOLACEUS*

Measurements in hundredths of length to caudal base; taken from fresh specimens

Locality .... (near)	Piedras Blancas	Pt. Purisima	Pt. Arguello	Pt. Arguello	Pt. Sal
Length in mm. to caudal	640	590	483	560	523
Length of head	15	14	14	14	14
Length of upper jaw	8	7	6	6	6
Length of eye	1.6	1.3	1.7	1.4	1.4
Length of snout	3.7	4.0	3.5	3.4	3.6
Width of suborbital	1.7	1.8	1.5	1.7	1.7
Width of bony interorbital	1 9	1.4	1.7	1.7	1.5
Eye to top of rostral crest	2.9	3.0	2.3	2.5	2.1
Eye to top of occipital crest	5.0	5.9	4.3	3.9	3.8
Cranium to top of occipital crest ...	2.9	3.9	1.9	1.6	1.5
Length of pectoral fin	5.0	5.6	6.6	5.9	5.9
Occiput to dorsal origin	6 4	6.7	6.6	5.9	6.5
Sex	♂	♂	♂	♀	♀
Gonad	large	small	small	empty	empty

Fin rays in nine specimens from central California: dorsal, XXII to XXV, 40 to 43; anal, II, 39 to II, 42.

GYMNOCLINUS Gilbert and Burke

Gymnoclinus Gilbert and Burke, Bull. U. S. Bur. Fish., 30, 1910 (1912), p. 86.

Adult material overlooked by Gilbert and Burke makes possible a fuller description of this interesting genus. In the original description the body was stated to be scaleless, the palate toothless, and the ventral fin one-rayed; whereas the body is covered with imbedded scales (barely apparent in the young types), the palate provided with conspicuous teeth, the ventral fin composed of a spine and two soft-rays. On the basis of the material at hand, the genus may be re-defined as follows:

Related, but not closely, to Bryostemma, Anoplarchus, and their allies. Body elongate and closely compressed, covered with small, imbedded scales. Lateral line developed only as a median row of disconnected pores; pores of sensory system of head conspicuous. Gill membranes broadly united and free from the isthmus. Gills complete; rakers short and slender (5 + 13 in number in the specimen examined); cheeks moderately tumid; a conspicuous median transverse interocular flap, trifid, with the middle flap the largest, and each division fringed; a very similar but smaller flap between the main one and a fleshy, almost horn-like protuberance at the end of the premaxillary process; this smaller median flap bounded on each side by two little fringed tentacles about half or two-thirds as long as the eye, not much larger than the conspicuous nasal tentacle; the flaps seem to be somewhat more fully fringed in the male than in the female; the adult male at hand has two additional simple tentacles in the mass on top of the snout; upper edge of upper lip at midline with several simple tentacles or barbels; lower edge of lip fringed around the teeth; no other flaps or filaments on head, but three dermal folds evident on top of head behind eyes. Mouth large, the jaws equal anteriorly and the upper extended backward beyond the eyes. A row of stout, bluntly conic teeth developed on edge of premaxillary along a little more than half its length, the series anteriorly bordering a somewhat triangular patch of smaller teeth. Mandibular teeth coarsely conic, in three series, the innermost consisting of a few large molars. Vomer with a rather small patch of blunt teeth, not widely separated from the large patch of dome-shaped molars which cover the palatines.

Gymnoclinus cristulatus Gilbert and Burke

Four specimens of this blenny, the basis of the description given above, were obtained by the *Albatross* on the shore of Simushir Island (Alaska) at Milne Bay, on June 23, 1906. Two of 72 mm. length are half grown, and approach the type of the species in general appearance, size of mouth, coloration, etc. Another is an adult male 109 mm. long to caudal; the other,

an adult female 116 mm. long, distended with eggs about 2 mm. in diameter.

The adults are nearly uniformly colored, with all the fins light except the dorsal; the vertical fins are without light bars, and the spots along the midline of the body are obsolete; a dark spot is developed above the gill-opening. The upper sides of the head are darker than the lower sides and surfaces; the break occurs on an oblique line passing through the eye; there is no conspicuous dark line between these two portions of the head. In the female, but not in the male at hand, the lighter part of the head is mottled, and the lips are crossed by light bars.

Dorsal fin composed of about sixty pungent and rather short spines, extending from above base of pectoral to base of the caudal, which is largely free, broadly rounded, and contains ten branched rays. The anal fin contains no spines, being composed of about forty (40 to 43) short unbranched rays. Pectoral broadly rounded, nearly half as long as head, composed of 14 rays. Ventrals greatly reduced, appearing as an adjacent pair of pointed flaps about two-thirds as long as the small eye. Each upon dissection, however, is found to be composed of two unbranched but articulated rays, and an exceedingly slender spine.

ALECTRIAS Jordan and Evermann

Alectrias Jordan and Evermann, Bull. U. S. Nat. Mus., 47, pt. 3, 1898, p. 2869; Jordan and Gilbert, Fur Seals and Fur-seal Islands, pt. 3, 1898, p. 482; Jordan and Snyder, Proc. U. S. Nat. Mus., 25, 1902, p. 475.

This genus, based on *Blennius alectrolophus* Pallas, and separated from Anoplarchus by Jordan and his associates, seems worthy of recognition.

Alectrias alectrolophus alectrolophus (Pallas)

Blennius alectrolophus Pallas, Zoog. Rosso-Asiat., 3, 1811, p. 174.

Gunnellus alectrolophus Cuvier and Valenciennes, Hist. Nat. Poiss., 11, 1836, p. 447.

Centronotus alectrolophus Günther, Cat. Fishes Brit. Mus., 3, 1861, p. 289.

Anoplarchus alectrolophus Bean, Proc. U. S. Nat. Mus., 4, 1881, p. 263; 4, 1881 (1882), p. 469; Jordan and Gilbert, Bull. U. S. Nat. Mus., 16.

1883, p. 771; Jordan, Proc. Acad. Nat. Sci. Phila., 1884, p. 103; Gill, Proc. U. S. Nat. Mus., 18, 1896, p. 150; Bean and Bean, *ibidem*, 19, 1896, p. 246; 19, 1896 (1897), p. 388; Grebnitsky, Messager Pêché, 12, 1897, p. 334; Jordan and Evermann, Bull. U. S. Nat. Mus., 47, pt. 3, 1898, pp. 2421 and 2869.

Anoplarchus atropurpureus Bean, in Nelson, Rept. Nat. Hist. Coll. Alaska, 1887, p. 300 and Nelson, *ibidem*, p. 305 (not of Kittlitz; material, from St. Michael's, Alaska, reëxamined).

Alectrias alectrolophus Jordan and Gilbert, Fur Seals and Fur-seal Islands, pt. 3, 1898, p. 482; Jordan and Snyder, Proc. U. S. Nat. Mus., 25, 1902, p. 477; Schmidt, Pisc. Mar. Orient., 1904, p. 175.

Alectrias alectrolophus alectrolophus ranges from the Okhotsk Sea to western Alaska (St. Michael).

Alectrias alectrolophus benjamini Jordan and Snyder

Alectrias benjamini Jordan and Snyder, Proc. U. S. Nat. Mus., 25, 1902, p. 475, fig. 16; Snyder, Proc. U. S. Nat. Mus., 42, 1912, p. 449; Jordan, Tanaka and Snyder, Journ. Coll. Sci., Imp. Univ. Tokyo, 33, 1913, p. 389, fig. 358.

This form, of northern Japan, is obviously the southern representative of *A. a. alectrolophus*, differing in having a larger head, deeper body, and fewer dorsal and anal rays and presumably fewer vertebrae. The recorded difference in the number of dorsal spines is as follows:

Dorsal Rays	55	56	57	58	59	60	61	62	63	64
A. a. alectrolophus	—	—	—	—	1	1	3	3	4	1
A. a. benjamini	2	—	1	2	—	—	—	—	—	—

These differences are exactly those which separate the southern *Anoplarchus purpurescens archolepis* from its northern representative, *A. p. insignis*, the range of which nearly coincides with that of *Alectrias a. alectrolophus;* these differences, furthermore, separate the climatic races of many other fishes. Although actual intergradation has not been observed, there can be little doubt that *benjamimi* will eventually be found to grade into typical *alectrolophus*.

ANOPLARCHUS Gill

As the precaudal parapophyses are widely divergent and the pyloric caeca are developed in Anoplarchus, this genus is referable to the Stichaeidae rather than to the Pholidae, in which group it has been erroneously located by Jordan and Evermann and other authors. It is very closely related to Alectrias and Alectridium, less closely to Chirolophus and its immediate allies. The lateral line in Anoplarchus is not obsolete, as frequently described, a row of spaced pores (visible to the unaided eye on the scaleless portion of the body) being developed along the midline of the fish.

This genus contains but one species, *A. purpurescens* Gill.

Anoplarchus purpurescens Gill

This species has long been identified as *Anoplarchus atropurpureus* (Kittlitz), but the *Ophidium atro-purpureum* of Kittlitz (1858) was certainly based on the blenny subsequently described by Jordan and Gilbert as *Xiphister rupestris*. Both his description and his figure are clearly taken from that form. Kittlitz also knew the present species, which he referred to as "Ophidium, species dritte," and which must now take the name next proposed, apparently that of *purpurescens* Gill. The references are given in the synonymy of the typical subspecies, *A. p. purpurescens*.

Anoplarchus purpurescens insignis Gilbert and Burke

Anoplarchus atropurpureus Bean, Proc. U. S. Nat. Mus., 4, 1881, pp. 245 (in part) and 271; Grebnitsky, Messager Pêché, 12, 1897, p. 334; Jordan and Gilbert, Fur Seals and Fur-seal Islands, pt. 3, 1898, p. 483; Schmidt, Pisc. Mar. Orient., 1904, p. 175; Evermann and Goldsborough, Bull. U. S. Bur. Fish., 26, 1906 (1907), p. 338 (in part); Gilbert and Burke, *ibidem*, 30, 1910 (1912), p. 88.

Anoplarchus insignis Gilbert and Burke, *ibidem*, p. 88, fig. 32.

This subspecies represents *Anoplarchus purpurescens* about the Aleutian Islands and in the Okhotsk Sea. It is distinguished especially by the increased number of dorsal and anal fin-rays and doubtless of vertebrae, for one ray is attached to each

vertebra (see account of *A. p. archolepis*). Average differences in proportions include the shorter head and trunk and longer tail and the slenderer body. Such characters often separate northern from southern forms. The color characters assigned to *insignis* are not distinctive, the types being merely of a highly variegated color phase. Other specimens are of plainer coloration, and both variegated and plain phases are developed in the two other subspecies.

Anoplarchus purpurescens purpurescens Gill

Ophidium, "Species dritte," Kittlitz, Denkwürdigkeiten einer Reise nach dem russischen Amerika, etc., 1, 1858, p. 225, fig. 3.

Anoplarchus purpurescens Gill, Proc. Acad. Nat. Sci. Phila., 1861, p. 262.

Centronotus crista galli Günther, Cat. Fishes Brit. Mus., 3, 1861, p. 289.

Anoplarchus crista galli Günther, *ibidem*, p. 564.

Anoplarchus alectrolophus Jordan and Gilbert, Proc. U. S. Nat. Mus., 3, 1880, p. 265; 3, 1880 (1881), p. 454 (in part); Jordan and Jouy, *ibidem*, 4, 1881, p. 4; Jordan and Gilbert, *ibidem*, p. 64 (in part).

Anoplarchus atropurpureus Jordan and Gilbert, Proc. U. S. Nat. Mus., 3, 1880, p. 265; Bean, *ibidem*, 4, 1881, p. 245; 4, 1881 (1882), p. 468; Jordan and Gilbert, Bull. U. S. Nat. Mus., 16, 1883, p. 771; Bean, Proc. U. S. Nat. Mus., 6, 1883 (1884), p. 354; Jordan, Rept. U. S. Comm. Fish., 1885, p. 910; Turner, Contr. Nat. Hist. Alaska, 1886, p. 93; Eigenmann and Eigenmann, Ann. N. Y. Acad., 6, 1892, p. 357; Jordan and Starks, Proc. Cal. Acad. Sci., (2) 5, 1895, p. 846; Gill, Proc. U. S. Nat. Mus., 18, 1895 (1896), p. 150; Starks, Proc. Calif. Acad. Sci., (2) 6, 1896, p. 562; Gilbert, Rept. U. S. Comm. Fish., 1893 (1896), p. 450; Jordan and Evermann, Bull. U. S. Nat. Mus., 47, pt. 3, 1898, p. 2422; pt. 4, 1900, fig. 845; Rutter, Bull. U. S. Fish Comm., 1898 (1899), p. 192; Jordan and Gilbert, Fur Seals and Fur-seal Islands, 3, 1899, p. 483; Osgood, N. Am. Fauna, 21, 1901, p. 20; Evermann and Goldsborough, Bull. U. S. Bur. Fish., 26, 1906 (1907), p. 338, fig. 112; Starks, Ann. Carn. Mus., 7, 1911, p. 212; Gilbert and Burke, Bull. U. S. Bur. Fish., 30, 1910 (1912), p. 88; Halkett, Check List Fishes Canada, 1913, p. 111; Miles, Publ. Puget Sound Biol. Sta., 2, 1918, pp. 79, 93; Kincaid, Annotated List Puget Sound Fishes, 1919, pp. 41, 42, fig. 96; Bean and Weed, Trans. Roy. Soc. Canada, (3) 13, 1919 (1920), pp. 81, 82.

Anoplarchus Fraser, Can. Field Nat., 35, 1921, p. 48.

The typical subspecies of *Anoplarchus purpurescens* occupies a wide range, and intergrades along the base of the Aleutian chain with *A. p. insignis*, and in northern California with *A. p. archolepis*. Series from Crescent City and Fort Bragg,

California, are rather arbitrarily referred to typical *purpurescens*, although definitely approaching *archolepis* both in scale and fin-ray characters: the scales extend forward as far as the fourth to seventh anal ray, rather than to above the fifth to ninth ray; the average number of dorsal spines is 56.18, one fewer than in more typical *purpurescens* (57.18) and but little higher than in *archolepis* (55.75). Specimens from Duxbury Reef, still farther south but yet north of San Francisco, fully bridge over the gap between these series and *A. p. archolepis:* the extent of the scaly area may be as in either subspecies, usually about on the border-line; the fin-ray average is intermediate. They are regarded as intergrades between *A. p. purpurescens* and *A. p. archolepis*.

Anoplarchus purpurescens archolepis, new subspecies

Anoplarchus alectrolophus Jordan and Gilbert, Proc. U. S. Nat. Mus., 3, 1880 (1881), p. 454 (in part); 4, 1881, p. 64 (in part). (Not of Pallas.)

Anoplarchus atropurpureus Jordan and Gilbert, Bull. U. S. Nat. Mus., 16, 1883, p. 771 (in part); Jordan and Evermann, *ibidem*, 47, pt. 3, 1898, p. 2422 (in part); Fowler, Proc. Acad. Nat. Sci. Phila., 72, 1920 (1921), p. 402. (Not of Kittlitz.)

Holotype, Cat. No. 55005, Museum of Zoölogy, University of Michigan: a specimen 150 mm. long to caudal base, collected by the writer in a low tide-pool on the reef at Carmel, Monterey County, California, on June 25, 1918. — Numerous paratypes, deposited in several institutions, were taken near the type-locality and at other points from the reefs just north of Pillar Point, San Mateo County, to Point Purisima in Santa Barbara County, California.

The sharpest characters of the new subspecies are indicated in the following analysis.

KEY TO THE SUBSPECIES OF *ANOPLARCHUS PURPURESCENS*

a[1]. Dorsal spines 60 to 63, usually more than 60; anal rays about 43 to 45 . . . . *A. p. insignis*

a[2]. Dorsal spines 53 to 61, usually fewer than 60; anal rays about 36 to 41.

- b[1]. Scaly area of body extended forward only as far as vertical from fourth to ninth anal rays . . . . *A. p. purpurescens*
- b[2]. Scaly area of body extended forward at least to above fourth anal ray, usually nearly to and sometimes even beyond, vertical from anus . . . . *A. p. archolepis*

In addition to the characters outlined above, certain other differences might be enumerated. On the average the head becomes relatively longer and the body plumper in the *insignis* to *purpurescens* to *archolepis* series, that is, from north to south. The latitudinal variation in the number of fin-rays in this species is striking.

LATITUDINAL VARIATION IN NUMBER OF DORSAL SPINES IN *ANOPLARCHUS PURPURESCENS*

Locality (and subspecies)	*Number of dorsal spines*												
	53	54	55	56	57	58	59	60	61	62	63	N	Av.
Okhotsk Sea and Aleutian Ids. (*insignis*)	—	—	—	—	—	—	—	3	5	2	1	11	61.09
Southern Alaska to Puget Sound (*purpurescens*)	—	2	9	11	18	23	9	1	1	—	—	74	57.18
Northern California: Crescent City, Fort Bragg (*purpurescens*)	1	2	6	10	5	1	1	2	—	—	—	28	56.18
Northern California Duxbury Reef (*intergrades*)	—	3	2	7	3	1	1	—	—	—	—	17	56.00
Central California: South of San Francisco (*archolepis*)	—	7	25	27	14	3	—	—	—	—	—	76	55.75

The counts used in the foregoing table are largely original, but include some from the literature. The marked similarity in the variation of the related *Alectrias alectrolophus* is noteworthy (see account of *A. a. benjamini*).

Description of type-specimen. — Body narrowly subrectangular, rather more robust than in *A. p. insignis*; depth, 7.25 in standard length; height of caudal base, 3.4 in head; length of head, 5.8 in length to caudal, relatively longer than in *A. p. insignis*; head symmetrically and rather broadly rounded in lateral aspect (more sharply pointed in young); a median crest extending from occiput to tip of snout (varying considerably in height; first developed after a length of about 40 mm. has been attained); eye, 5.5 in head; snout, 4.3; upper jaw extending to vertical from posterior margin of eye, 2.3; jaws equal an-

teriorly. Band of teeth in each jaw narrowing posteriorly to a single series of strong teeth, which is continued forward to the front of the jaw on the outside of the band in the upper jaw, but on the inside of the band in the lower jaw. Gill-membranes united to the sides of the isthmus, not forming a fold; isthmus as wide as orbit. Posterior nostril tubular; a row of prominent pores about eye.

Scales small, roundish, imbedded; in 118 series (running upward and forward) from the origin of the scaly area above the second anal ray to the caudal base; scales extended forward along anal base nearly to (in some specimens quite to) the anus. Lateral line median, composed of simple, separated pores.

Dorsal, LVI; anal, 39. Origin of dorsal as distant as eye from occiput; anterior dorsal spines rather weak, gradually becoming more robust posteriorly, those behind the anus rather strong; dorsal spines highest a little in advance of end of fin, 3.6 in head; anterior branch of last anal ray, 2.7. Dorsal and anal fins barely joined, the dorsal the less narrowly, to the caudal fin; length of caudal contained 1.7 times in the head; length of pectoral, 2.6 times.

(*Archolepis* = anus + scale, so named from the fact that in this subspecies the scales extend forward to, or nearly to, the anus.)

DELOLEPIS Bean

Orthotype. — *Delolepis virgatus* Bean (= *Ophidium giganteum* Kittlitz).

Delolepis giganteus (Kittlitz)

The name *Ophidium giganteum* [6] may be revived for this species, upon which it was doubtless based. The type-locality (Sitka), the huge size, the number of fin-rays, the coloration, etc., could apply to no other known fish. There are some discrepancies between the description of Kittlitz and that of Bean,

[6] Kittlitz, *Denkwürdigkeiten einer Reise nach dem russischen Amerika, etc.,* 1858, p. 226. I am indebted to Dr. W. H. Osgood for the loan of a copy of this rare book.

but these are doubtless due to inaccuracies in Kittlitz's account, which is based solely upon field notes. His inaccurate statement in parenthesis regarding the depth and thickness of the body, given in the past tense, would appear to be based on memory. The original description of Kittlitz, heretofore overlooked, may be reprinted, as his work is not readily accessible:

Von einer auffallend groszen Art der nämlichen Form [three other species of Stichaeidae described and figured above] sah ich nur einmal ein Examplar, welches an Bord des Seujourn an der Angel gefangen worden war. Ich habe damals nur einige kurze Notizen über diesen merkwürdigen Fisch aufgezeichnet, dem ich, wenn er wirklich noch unbeschrieben wäre, den Namen *Ophidium giganteum* geben möchte. Länge: drei Fusz zehn zoll (englisches Maasz), (der Körper war ungefähr neun zoll hoch und höchstens drei zoll dick). Kiem enhaut sechs Strahlen, Rückenflosse 77, Afterflosse 49, Brustflosse 12. Zähne ziemlich stark, unter stärker als oben, unten nur eine deutliche Reihe, ober zwei Reihen doppelt gestellter Zähne, doch im Gaumen keine. Kiemendeckel einfach, Kopf sehr höckerig, das Ganze mit einer schleimigen, schuppenlosen Haut bedeckt. Die Seitenlinie besteht aus einer graden Reihe warziger Erhabenheiten, über der eine zweite sehr undeutliche läuft; beide werden durch dunklere Färbung kenntlich. Ganzer körper hellaschgrau, ins Silberfarbige ziehend.

LUMPENELLA, new genus

Orthotype — *Lumpenus longirostris* Evermann and Goldsborough.

Body elongate, covered with small cycloid scales; no lateral line; head pointed, the snout produced somewhat beyond the small horizontal mouth; eye elliptical in outline; vertical fins slightly confluent, the dorsal composed entirely of stiff, rather high, spines, the anal of three to five (usually five) spines and about forty soft-rays; pelvics small, with a spine and two soft-rays. Allied to Lumpenus, but differing widely in the form of the head, snout, and eyes, and in the increased number of anal spines.

(Lumpenella: diminutive of Lumpenus.)

Lumpenella longirostris (Evermann and Goldsborough)

Lumpenus longirostris Evermann and Goldsborough, Bull. U. S. Bur. Fish., 26, 1906 (1907), p. 340, fig. 115.

We offer here a description of the young of this species, drawn up from a specimen 75 mm. long to caudal fin, taken by

the *Albatross* at Station 2855, near Kodiak Island, Alaska, at a depth of 68 fathoms.

Body moderately compressed and greatly elongated, as in the species of Lumpenus; the dorsal and ventral contours parallel from nape to anus; the depth in this region contained about 2 times in the head, about 12 times in length to caudal; depth just before base of caudal, 5.5 in head. Length of head little more than half its distance from origin of anal, contained 6 times in total. Head rather sharply pointed, the snout projecting a short distance beyond the mouth; head thin dorsally, the elliptical eyes narrowly separated (interorbital about one-fourth eye). Snout and eye each contained 3.8 times in head; the upper jaw, about 4.5 times. Eyes without free margin. Gill-opening extending forward to below eye; gill-rakers very short, but not widely spaced.

Dorsal fin beginning above insertion of the pelvics, a little before the vertical from end of opercle; composed entirely of stiff spines about 65 in number, the largest, just behind middle of body, about as long as eye; anal fin with 5 spines like those of the dorsal, and 39 soft-rays (the last counted as split to base). Pectoral apparently normal in form, composed of 13 rather weak rays, the lowermost as strong as any of the others.

Scales very small and rounded, with entire edges, apparently covering entire body and the cheeks, at least, of the head. Lateral line not evident.

No distinctive color markings.

PLAGIOGRAMMUS Bean

This genus is not closely related to *Dictyosoma*, with which it has been aligned, as it differs fundamentally in the entire lack of dorsal soft-rays (a specialized feature) and in the better development of the paired fins (a generalized feature). It shows closer relationships with the Chirolophinae, the Plectobranchinae and the Stichaeinae, as defined by Jordan and Evermann, but agrees wholly with none. Perhaps its closest ally is to be looked for in the genus Ozorthe of Japan.

Plagiogrammus hopkinsi Bean

Plagiogrammus hopkinsi Bean, Proc. U. S. Nat. Mus., 16, 1893 (1894), p. 699, fig.; Jordan and Evermann, Rept. U. S. Comm. Fish., 1895 (1896), p. 475; Bull. U. S. Nat. Mus., 47, pt. 3, 1898, p. 2482; Snyder, Proc. U. S. Nat. Mus., 35, 1908, p. 185.

The type-material of this peculiar blenny was collected near Monterey, California, by students of the Hopkins Seaside Laboratory, and forwarded to Chicago for exhibition in the Aquarium of the World's Columbian Exposition; the species was here discovered by Dr. Tarleton H. Bean, and was described by him in 1894. The species was not again noted until Professor J. O. Snyder secured several topotypes in a low tide-pool on Pt. Pinos, which he recorded in 1908. The writer collected by poison the four additional known examples of the species in rather deep, low rock-pools on the reefs at Carmel and Point Lobos, a few miles farther south.

Dorsal spines XLI in all our specimens; anal rays II, 27 in one and II, 28 in three, counting the last ray as double.

PHYTICHTHYS Hubbs

Xiphistes Jordan and Starks, Proc. Calif. Acad. Sci., (2) 5, 1895, p. 846; Jordan and Evermann, Bull. U. S. Nat. Mus., 47, pt. 3, 1898, p. 2423.

Phytichthys Hubbs MS., *in* Jordan, Stanford Univ. Publ., (Biol.) 3, 1923, p. 234.

Genotype: *Xiphister chirus* Jordan and Gilbert, 1880.

This name replaces that of Xiphistes Jordan and Starks, 1895, with the same type-species, that name being preoccupied by Xiphistes Stål, 1895, a genus of bugs.

Phytichthys is closely related only to Xiphister and Epigeichthys, forming with these genera a group which Jordan and others have elevated to family rank. They agree in having no pelvic fins and the pectoral fins reduced in size, the dorsal composed wholly of spines; the lateral lines four, each with many short branches not uniting to form a network. The distinctive features of Phytichthys may be outlined as follows:

	Phytichthys	Xiphister and Epigeichthys
Anal spines:	II (rarely III)	Lacking
Pectoral fin:	Longer than eye	As short as or shorter than eye
Lower lateral line and abdominal line:	Not connected	Connected
Premaxillary canines:	About four	Two
Body:	More compressed	More terete
Colors:	Bright; varied	Dull

(Phytichthys = plant + fish, so named in allusion to the fact that the species of this genus live in the dense vegetation of the tidal zone, whereas the species of related genera live under boulders.)

Phytichthys chirus (Jordan and Gilbert)

The three nominal species of Xiphistes (= Phytichthys) are apparently reducible to two intergrading subspecies or climatic forms, strikingly analogous to those of Anoplarchus, Alectrias and related genera. They are separable by means of the following characters.

KEY TO THE SUBSPECIES OF *PHYTICHTHYS CHIRUS*

a^1. Dorsal spines 74 to 77; head in adult contained 8.75 to 10.35 times in length without caudal: Aleutian Islands................*P. c. versicolor*

a^2. Dorsal spines 70 to 74; head in adult contained 6.7 to 8.7 times in standard length: British Columbia to central California....*P. c. chirus*

The rather few available counts of dorsal spines are given in the following table. These are insufficient finally to prove the intergradation of the two forms, but it is extremely probable that the two forms will be found to merge into one another.

Counts of Dorsal Spines in the Subspecies of *Phytichthys chirus*

Series Number (data follows)	Locality	Dorsal spines							
		70	71	72	73	74	75	76	77
1	Attu Id., Aleutian Ids.	—	—	—	—	—	1	—	—
2	Attu or Aggattu Id.	—	—	—	—	1	2	1	1
3	Attu Id., Aleutian Ids.	—	—	—	—	—	3	2	—
4	Amchitka Id., Aleutian Ids.	—	—	—	—	—	1	—	1
5	Waada Id., Washington	—	—	—	—	1	—	—	—
6	Port Orchard, Washington	—	—	—	2	—	—	—	—
7	Puget Sound, Washington		12		1	—	—	—	—
8	Monterey, California	1	1	—	—	—	—	—	—
9	Monterey, California	1	—	—	—	—	—	—	—

Series 1 and 2. — The type and five paratypes, respectively, of *Xiphistes versicolor;* the counts published by Gilbert and Burke (1912).

Series 3. — Original counts on five paratypes of *X. versicolor*, perhaps in part duplicating those of Gilbert and Burke.

Series 4. — Original counts of two specimens collected by Dall and reported on by Bean (1881).

Series 5. — The types of *Xiphistes ulvae;* as described by Jordan and Starks.

Series 6. — Counts of two specimens in the National Museum.

Series 7. — Original counts of 13 specimens from Puget Sound.

Series 8. — Original counts of two of the types of *Xiphister chirus*.

Series 9. — The count given by Jordan and Gilbert in their type description of *X. chirus*.

Phytichthys chirus versicolor (Gilbert and Burke)

Xiphister chirus Bean, Proc. U. S. Nat. Mus., 4, 1881, p. 245.

Xiphistes chirus Jordan and Evermann, Bull. U. S. Nat. Mus., 47, pt. 4, 1900, p. 3303, fig. 837; Jordan, Guide to the Study of Fishes, 2, 1905, fig. 458; Evermann and Goldsborough, Bull. U. S. Bur. Fish., 26, 1906 (1907), p. 339, fig. 113.

Xiphistes versicolor Gilbert and Burke, Bull. U. S. Bur. Fish., 30, 1910 (1912), p. 88, fig. 33.

This subspecies is known only from the Aleutian Islands, but it doubtless ranges eastward and southward along the Alaskan coast, and in all probability grades into typical *P. chirus.*

Phytichthys chirus chirus (Jordan and Gilbert)

Xiphister chirus Jordan and Gilbert, Proc. U. S. Nat. Mus., 3, 1880, pp. 135, 138 and 265; 3, 1880 (1881), p. 454; Jordan and Jouy, *ibidem,* 4, 1881, p. 4; Jordan and Gilbert, *ibidem,* p. 64; Bull. U. S. Nat. Mus., 16, 1883, p. 772; Jordan, Rept. U. S. Comm. Fish., 1885, p. 910; Eigenmann and Eigenmann, Ann. N. Y. Acad. Sci., 6, 1892, p. 357.

Xiphistes chirus Jordan and Starks, Proc. Calif. Acad. Sci., (2) 5, 1895, p. 846; Jordan and Evermann, Rept. U. S. Comm. Fish., 1895 (1896), p. 475; Bull. U. S. Nat. Mus., 47, pt. 3, 1898, p. 2424; Osgood, N. Am. Fauna, 21, 1901, p. 20; Starks, Ann. Carn. Mus., 7, 1911, p. 200; Halkett, Check List Fishes Canada, 1913, p. 111; Miles, Publ. Puget Sound Biol. Sta., 2, 1918, p. 80; Kincaid, Annotated List Puget Sound Fishes, 1919, p. 42 (the copied fig. 97 based on *P. c. versicolor*).

Xiphidion chirus Regan, Ann. Mag. Nat. Hist., (8) 10, 1912, p. 272, fig. 3.

Xiphistes ulvae Jordan and Starks, Proc. Calif. Acad. Sci., (2) 5, 1895, p. 847, pl. 102; Jordan and Evermann, Bull. U. S. Nat. Mus., 47, pt. 3, 1898, p. 2423; Gilbert and Burke, Bull. U. S. Bur. Fish., 30, 1910 (1912), p. 89; Bean and Weed, Trans. Roy. Soc. Canada, (3) 1919 (1920), p. 82.

According to Starks (1911) the nominal species *X. ulvae* in all probability is a synonym of *X. chirus.* The variation in the length of the branches of the upper lateral line, he found, has not the taxonomic value attributed to it in the original description of *ulvae.* Furthermore the number of anal spines, III, in the type of *ulvae* presumably is an infrequent variation, the normal number for the genus being II.

XIPHISTER Jordan

Xiphidion Girard, U. S. Pac. R. R. Surv., 6, pt. 4, 1857, p. 20; 10, pt. 4, 1858, p. 119; Jordan and Evermann, Bull. U. S. Nat. Mus., 47, pt. 3, 1898, p. 2424; Regan, Ann. Mag. Nat. Hist., (8) 10, 1912, p. 272 (in part). (Name preoccupied by *Xiphidion* Seville, 1831, a genus of grasshoppers, a name later corrected in form to read Xiphidium.)

Xiphidium Cope, Proc. Am. Phil. Soc., 1873, p. 27 (altered spelling).

Xiphister Jordan, Proc. U. S. Nat. Mus., 2, 1879 (1880), p. 241; Jordan and Gilbert, Bull. U. S. Nat. Mus., 16, 1883, p. 771 (in part); Jordan, Copeia, no. 49, 1917, p. 87; The Genera of Fishes, pt. 3, 1919, pp. 290 and 400; The Classification of Fishes, 1923, p. 234.

Xiphister mucosus (Girard)

Xiphidion mucosus Girard, U. S. Pac. R. R. Surv., 6, pt. 4, 1857, p. 20.

Xiphidion mucosum Girard, *ibidem,* 10, pt. 4, 1858, p. 119; Günther, Cat. Fishes Brit. Mus., 3, 1861, p. 291; Jordan and Starks, Proc. Cal. Acad. Sci., (2) 5, 1895, p. 848; Gilbert, Rept. U. S. Comm. Fish., 1893 (1896), p. 470; Jordan and Evermann, *ibidem,* 1895 (1896), p. 475; Bull. U. S. Nat. Mus., 47, pt. 3, 1898, p. 2425; Osgood, N. Am. Fauna, 21, 1901, p. 20; Evermann and Goldsborough, Bull. U. S. Bur. Fish., 26, 1906 (1907), p. 339; Starks, Ann. Carn. Mus., 7, 1911, p. 200; Halkett, Check List Fishes Canada, 1913, p. 111; Starks, The Sesamoid Articular (Stanford Univ. Publ., Biol. Ser.), 1916, p. 35 (generic name spelled Ziphidion); Miles, Publ. Puget Sound Biol. Sta., 2, 1918, pp. 79, 89, 93; Kincaid, Annotated List Puget Sound Fishes, 1919, p. 42; Bean and Weed, Trans. Roy. Soc. Canada, (3) 13, 1919 (1920), p. 82.

Xiphidium mucosum Cope, Proc. Am. Phil. Soc., 1873, p. 27; Steindachner, Denksch., Akad. Wiss. Wien, 70, 1900, p. 483.

Xiphister mucosus Jordan, Proc. U. S. Nat. Mus., 2, 1879 (1880), p. 241; Jordan and Gilbert, *ibidem,* 3, 1880, pp. 137, 265; 3, 1880 (1881), p. 454; Jordan and Jouy, *ibidem,* 4, 1881, p. 4; Jordan and Gilbert, *ibidem,* p. 64; Bean, *ibidem,* p. 263; 4, 1881 (1882), p. 468; Jordan and Gilbert, Bull. U. S. Nat. Mus., 16, 1883, p. 772; Bean, Proc. U. S. Nat. Mus., 6, 1883 (1884), pp. 354 and 364; Jordan, Rept. U. S. Comm. Fish., 1885, p. 910; Eigenmann and Eigenmann, Ann. N. Y. Acad. Sci., 6, 1892, p. 357; Jordan, Copeia, No. 95, 1921, p. 36.

Xiphister mucosum Kermode, Provincial Museum of Natural History and Ethnology, Victoria, 1909, p. 89.

Xiphidium cruoreum Cope, Proc. Am. Phil. Soc., 1873, p. 27.

Xiphister cruoreum Jordan and Gilbert, Proc. U. S. Nat. Mus., 3, 1880, p. 138.

This species ranges from Alaska (whence it has been reported by several authors, and lately secured on Forester Island by Dr. Harold Heath) southward to San Simeon Bay, central California. The type-locality is the "South Farallon Islands," off San Francisco.

EPIGEICHTHYS, new genus

Orthotype. — *Xiphister rupestris* Jordan and Gilbert.

The two species currently referred to Xiphister (or Xiphidion), on close examination are found to differ in so many respects that they are here referred to distinct genera. The name Xiphister is to be retained for *mucosus*, while a new generic name is required for *rupestris* (= *atro-purpureus*).

In *Epigeichthys atro-purpureus* the frontal portion of the cranium is elevated, swollen and rather strongly arched, whereas in *Xiphister mucosus* it is rather evenly and gently curved in dorsal profile. The occipital portion of the cranium in sharp contrast is rather strongly depressed (in Xiphister not much more depressed than the frontal region). The premaxillary canines are not normally separated by a pair of smaller teeth as they are in Xiphister (in that genus there may be but one intermediate tooth, and the one or two may be almost as long as the canines proper). The outer two mandibular canines are typically much larger than the inner pair, the discrepancy in size being usually greater than in Xiphister. The inner band of teeth at its widest point is much narrower, instead of about as wide as eye. The origin of the dorsal fin is less distant than is the tip of snout from the occiput, rather than the reverse. The dorsal spines are usually fewer instead of more than 70 in number (in 11 specimens, taken at points in California from Crescent City to Cambria, the dorsal spines vary in number from 63 to 71; the anal rays, from 50 to 52). The pectoral fins are minute, shorter than the very small eye, whereas in Xiphister they are quite as long as the eye.

(Epigeichthys: the fish so named from the fact that it characteristically assumes, even as adult, an epigean habitat on the retreat of the tide, living then in merely damp situations under boulders; the young only of Xiphister share this peculiar habit and habitat with Epigeichthys.)

Epigeichthys atro-purpureus (Kittlitz)

Ophidium atro-purpureum Kittlitz, Denkwürdigkeiten einer Reise nach dem russischen Amerika, 1, 1858, p. 225, fig. 1 (not *Anoplarchus atropurpureus* of later authors).

Xiphister rupestris Jordan and Gilbert, Proc. U. S. Nat. Mus., 3, 1880, pp. 137 and 265; *ibidem*, 3, 1880 (1881), p. 454; Jordan and Jouy, *ibidem*, 4, 1881, p. 4; Jordan and Gilbert, *ibidem*, p. 64; Bean, *ibidem*, pp. 245 and 271; Jordan and Gilbert, Bull. U. S. Nat. Mus., 16, 1883, p. 773; Jordan, Rept. U. S. Comm. Fish and Fish., 1885, p. 910; Eigenmann and Eigenmann, Ann. N. Y. Acad. Sci., 6, 1892, p. 357.

Xiphidion rupestre Jordan and Starks, Proc. Calif. Acad. Sci., (2) 5, 1895, p. 848, pl. 103; Jordan and Evermann, Rept. U. S. Comm. Fish and Fish., 1895 (1896), p. 454; Bull. U. S. Nat. Mus., 47, pt. 3, 1898, p. 2426; pt. 4, 1900, pl. 344, fig. 838; Osgood, N. Am. Fauna, 21, 1901, p. 20; Evermann and Goldsborough, Bull. U. S. Bur. Fish., 26, 1906 (1907), p. 339, fig. 114; Metz, Ann. Rept. Laguna Mar. Lab., 1, 1911 (1912), p. 60, figs. 30, 31; Starks, Ann. Carn. Mus., 7, 1911, p. 200; Halkett, Check List Fishes Canada, 1913, p. 111; Kincaid, Annotated List Puget Sound Fishes, 1919, p. 42, fig. 100; Bean and Weed, Trans. Roy. Soc. Canada, (3) 13, 1919 (1920), p. 82; Fowler, Proc. Acad. Nat. Sci. Phila., 72, 1920 (1921), p. 402; 75, 1923, p. 283.

This species is currently known under the name *Xiphidion rupestre*, proposed by Jordan and Gilbert, as *Xiphister rupestris*, in 1880. The earlier name of Kittlitz, however, is without question based on the same species, the figure being readily recognizable. Why Kittlitz's name *atro-purpureum* should have been adopted by Bean and by Jordan and Gilbert and subsequent authors for the very different *Anoplarchus purpurescens* Gill is not evident, especially as Kittlitz described and figured the latter form (as "Ophidium Species dritte") on the same page. Probably most workers have not had access to Kittlitz's rare volume.

Epigeichthys atro-purpureus ranges from immediately south of Point Arguello, Santa Barbara County, California, northward to southeastern Alaska. Among other specimens from Alaska which we have seen are several taken by Dr. Harold Heath on Forester Id.

Epigeichthys atro-purpureus is a species of the intertidal zone of the exposed reefs. It lives, even as adult, beneath boulders, remaining there, in merely moist situations, when the tide

recedes. It shares this habitat with the young, but not the adult, of *Xiphister mucosus*. The present species does not attain so large a size as *Xiphister mucosus*, reaching a length of not more than twelve instead of more than twenty inches.

In coloration also these two species differ. The young of *E. atro-purpureus* are greenish-black; those of *X. mucosus*, pale translucent olive. The adult of *atro-purpureus* is usually more blackish than *mucosus*, and shows, toward the caudal fin, only traces of the dusky, yellowish or whitish mottlings which are characteristically developed in that species.

Other color and coloration differences appear on comparing the radial markings of the head. In both species — in fact in all the elongate northern blennies — these head-markings radiating from the eye are, obviously, serially continuous with the vertical bars of the body, and appear to be homologous throughout the series of genera, although usually so modified as to be diagnostic of the various species. The most primitive conditions are doubtless retained in those species in which the barred type of coloration is best developed. The bars on the head are more or less sharply angulated medially toward the eye. They are formed and located as follows: *bar 1*, on the snout, angulated and often obsolete, or represented only by the lower branch, extending from eye to middle of lower jaw; *bar 2*, composed of an upper branch extending from the eye upward, and bent toward the opposite direction from that taken by the lower branch, and a lower branch extending downward just behind the mouth, being directed obliquely forward in the small-mouthed forms, obliquely backward in those having a large mouth; *bar 3*, primitively nearly parallel with the second, becoming more sharply angulated until the lower branch is horizontal, while the upper branch extends to the occiput; *bar 4*, extending from nape downward across opercles, usually largely disintegrated or obsolete. *Xiphister mucosus* and *Epigeichthys atro-purpureus* differ constantly in the details of the color and proportions of these radial streaks of the head, as Jordan and Gilbert accurately and clearly noted in the original account of *Xiphister rupestris* = *E. atro-purpureus*). In *X. mucosus*, "radiating backward from the

eye are three olive-brown streaks, these much lighter in the center and edged above and below with blackish, outside of which is sometimes a streak of light green. These streaks all merge backward in the olive-green of the head. The upper streak [upper branch of *bar 3*] from the eye toward the occiput is generally obsolete or small and indistinct; the middle streak [lower branch of *bar 3*] is wedge-shape, with the edges straight or nearly so; it is but slightly more than one-third the length of the head; the third streak [lower branch of *bar 2*] terminates before reaching the margin of the preopercle." In *E. atropurpureus*, although these streaks are doubtless homologous, they differ in the following respects: "Three long, well-defined streaks radiating backward from the eye, these streaks uniform black, overlying the olive cheeks, and abruptly margined with very light olive; the upper streak [upper branch of *bar 3*] is more distinct than in *X. mucosus;* the central streak [lower branch of *bar 3*] proceeds straight backward from the eye, half the breadth of the cheeks, at which point it is broadest; it is then narrowed and bent abruptly downward; both the middle and lower [lower branch of *bar 2*] reach the margin of the preopercle, the length of the middle streak being seven-tenths that of the head."

PHOLIDAE

As Boulenger [7] and Regan [8] have indicated, Pholis and its allies differ sufficiently from the Stichaeidae to deserve family distinction. The chief characters diagnostic of the family are the anomalous union of the precaudal parapophyses to form haemal arches, and the lack of pyloric caeca along the straight alimentary canal. The differences in visceral anatomy are correlated with food, the Stichaeidae being chiefly herbivorous, the Pholidae carnivorous. It is possible that the union of the precaudal parapophyses may also be traced to the nature of the food of these fishes, as in the Pholidae the visceral organs are relatively small, compact and constricted laterally, so that the

[7] Boulenger, *Cambr. Nat. Hist.*, 7, 1904, p. 711.
[8] Regan, *Ann. Mag. Nat. Hist.*, (8) 10, 1912, p. 273.

body cavity is much narrower dorsally. The consequent approximation of the body wall below the vertebral column may have permitted the union of the parapophyses.

KEY TO THE GENERA OF PHOLIDAE INHABITING THE NORTHEASTERN PACIFIC

a[1]. Anal spines two, small and unmodified. Pelvic fins present (though very small). Pectoral fin of moderate size (Pholinae).............*Pholis*

a[2]. Anal spine single, more or less enlarged, pen-shaped, recumbent and fitting into a dermal sheath. Pelvic fins wholly undeveloped (**Apodichthyinae**, new subfamily name)

- b[1]. Pectoral fin of moderate size at all ages. Anal spine very large, and channeled along anterior edge[9]; dorsal spines 90 to 94[10]; anal soft-rays 40 to 42.[11]........................*Apodichthys*
- b[2]. Pectoral fin minute (at all ages). Anal spine small, not channeled. Dorsal spines 83 to 85[12]; anal soft-rays, 33 to 36.[13]....*Xererpes*
- b[3]. Pectoral fin wholly absent. Anal spine still smaller than in Xererpes, and not channeled.[14]..........................*Ulvicola*

PHOLIS Scopoli

Pholis ornatus (Girard)

Gunnellus ornatus Girard, Proc. Acad. Nat. Sci. Phila., 7, 1854, p. 149; U. S. Pac. R. R. Surv., 6, pt. 4, 1857, p. 18; 10, pt. 4, 1858, p. 116, pl. 25b, figs. 6, 7; Suckley, *ibidem*, 12, book 2, 1860, p. 355, pl. 25b, figs. 6, 7.

Muraenoides ornatus Jordan and Gilbert, Proc. U. S. Nat. Mus., 3, 1880 (1881), p. 454; Jordan and Jouy, *ibidem*, 4, 1881, p. 4; Jordan and Gilbert, *ibidem*, p. 63; Bean, *ibidem*, pp. 147 and 245; 4, 1881 (1882), p. 469; Jordan and Gilbert, Bull. U. S. Nat. Mus., 16, 1883, p. 766; Bean, Proc. U. S. Nat. Mus., 6, 1883 (1884), p. 354; Jordan, Rept. U. S. Comm. Fish and Fish., 1885, p. 910; Turner, Contr. Nat. Hist. Alaska, 1886, p. 93; Bean, in Nelson, Rept. Nat. Hist. Coll. Alaska, 1887, p. 300; Nelson, *ibidem*, p. 305; Eigenmann and Eigenmann, Ann. N. Y. Acad. Sci., 6, 1892, p. 357; Kermode, Provincial Museum of Natural History, Victoria, 1909, p. 89.

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[9] In a young specimen of Apodichthys 24 mm. long, to caudal, the anal spine is ungrooved and small, as in the adult of Xererpes, but it is already excavate in one 27 mm. long.

[10] In 13 specimens from northern and central California.

[11] In 8 examples from California.

[12] In 11 specimens from Santa Barbara County, California.

[13] In two from the same county.

[14] The structure of the gill-opening in Ulvicola, contrary to current descriptions, is normal, and like that of Xererpes.

Pholis ornatus Jordan and Starks, Proc. Cal. Acad. Sci., (2) 5, 1895, p. 845; Starks, *ibidem*, (2) 6, 1896, p. 562; Gill, Proc. U. S. Nat. Mus., 18, 1895 (1896), p. 150; Gilbert, Rept. U. S. Comm. Fish and Fish., 1893 (1896), p. 450; Jordan and Evermann, *ibidem*, 1895 (1896), p. 474; Bean and Bean, Proc. U. S. Nat. Mus., 19, 1896, p. 247; Bull. U. S. Nat. Mus., 47, pt. 3, 1898, p. 2419; pt. 4, 1900, fig. 833; Jordan and Gilbert, Fur Seals and Fur-seal Islands, pt. 3, 1899, p. 481; Rutter, Bull. U. S. Fish Comm., 1898 (1899), p. 192; Townsend, Rept. U. S. Comm. Fish., 1900 (1901), p. 184; Osgood, N. Am. Fauna, 21, 1901, p. 20; Schmidt, Pisc. Mar. Orient., 1904, p. 174; Evermann and Goldsborough, Bull. U. S. Bur. Fish., 26, 1906 (1907), pp. 310, 338, fig. 111; Evermann and Latimer, Proc. Biol. Soc. Wash., 23, 1910, p. 139; Starks, Ann. Carn. Mus., 7, 1911, p. 199; Bean and Weed, Smiths. Misc. Coll., 52, 1910, p. 458; Pavlenko, Trd. Obšč. Jest., Kazanî, 42, 1910, p. 48; Gilbert and Burke, Bull. U. S. Bur. Fish., 30, 1910 (1912), p. 87; Halkett, Check List Fishes Canada, 1913, p. 111; Miles, Publ. Puget Sound Biol. Sta., 2, 1918, 79; Kincaid, Annotated List Puget Sound Fishes, 1919, p. 41, fig. 95; Bean and Weed, Trans. Roy. Soc. Canada, (3) 13, 1919 (1920), p. 81.

Ophidium, "zweite Species," Kittlitz, Denkwürdigkeiten einer Reise nach dem russischen Amerika, 1, 1858, p. 225, fig. 2.

Centronotus nebulosus Günther, Cat. Fishes Brit. Mus., 3, 1861, p. 287 (in part).

Centronotus laetus Cope, Proc. Am. Phil. Soc., 1873, p. 27.

Muraenoides laetus Jordan and Gilbert, Proc. U. S. Nat. Mus., 3, 1880, p. 265; 3, 1880 (1881), p. 454; 4, 1881, p. 63.

This blenny ranges from San Francisco Bay to the Aleutian Islands and the Okhotsk Sea.

Pholis dolichogaster (Pallas)

We have examined 14 specimens collected by the *Albatross* at Milne Bay, Simushir Id., Alaska, on June 23, 1906.

Some of these are plain in colors; others show black dots surrounding pale spots along midline of sides; the largest example (157 mm. to caudal) is dusted over the sides with black spots.

APODICHTHYS Girard

Apodichthys flavidus Girard

Apodichthys flavidus Girard, Proc. Acad. Nat. Sci. Phila., 7, 1854, p. 150; U. S. Pac. R. R. Surv., 6, pt. 4, 1857, p. 19; 10, pt. 4, 1858, p. 117; Günther, Cat. Fishes Brit. Mus., 3, 1861, p. 290; Gill, Proc. Acad. Nat. Sci. Phila., 14, 1862, p. 279; Jordan and Gilbert, Proc. U. S. Nat. Mus.,

3, 1880, pp. 140, 265; 3, 1880 (1881), p. 454; Jordan and Jouy, *ibidem*, 4, 1881, p. 4; Jordan and Gilbert, *ibidem*, p. 64; Bean, *ibidem*, p. 263; Bull. U. S. Nat. Mus., 16, 1883, p. 769; Jordan, Rept. U. S. Comm. Fish and Fish., 1885, p. 910; Eigenmann and Eigenmann, Ann. N. Y. Acad. Sci., 6, 1892, p. 357; Jordan and Starks, Proc. Cal. Acad. Sci., (2) 5, 1895, p. 845; Starks, *ibidem*, (2) 6, 1896, p. 562; Jordan and Evermann, Rept. U. S. Comm. Fish and Fish., 1895 (1896), p. 473; Bull. U. S. Nat. Mus., 47, pt. 3, 1898, p. 2411; pt. 4, 1900, p. 3302, fig. 830; Jordan, Guide to the Study of Fishes, 2, 1905, p. 512; Evermann and Goldsborough, Bull. U. S. Bur. Fish., 26, 1906 (1907), p. 336, fig. 108; Kermode, Provincial Museum of Natural History and Ethnology, Victoria, 1909, p. 89; Starks, Ann. Carn. Mus., 7, 1911, p. 199; Halkett, Check List Fishes Canada, 1913, p. 110; Jordan, The Genera of Fishes, pt. 2, 1919, p. 258; Kincaid, Annotated List Puget Sound Fishes, 1919, p. 41; Bean and Weed, Trans. Roy. Soc. Canada, (3) 13, 1919 (1920), p. 81.

Apodichthys flavidus flavidus Jordan and Evermann, Bull. U. S. Nat. Mus., 47, pt. 3, 1898, p. 2411.

Apodichthys virescens Ayres, Proc. Cal. Acad. Sci., 1855, p. 55; Girard, U. S. Pac. R. R. Surv., 6, pt. 4, 1857, p. 19; 10, pt. 4, 1858, p. 118; Gill, Proc. Acad. Nat. Sci. Phila., 14, 1862, p. 279.

Apodichthys flavidus virescens Jordan and Evermann, Bull. U. S. Nat. Mus., 47, pt. 3, 1898, p. 2411.

Apodichthys sanguineus Gill, Proc. Acad. Nat. Sci. Phila., 14, 1862, p. 279.

Apodichthys flavidus sanguineus Jordan and Evermann, Bull. U. S. Nat. Mus., 47, pt. 3, 1898, p. 2411.

Apodichthys inornatus Gill, Proc. Acad. Nat. Sci. Phila., 14, 1862, p. 279, footnote; Jordan and Gilbert, Proc. U. S. Nat. Mus., 3, 1880, p. 140.

Apodichthys univittatus Lockington, Proc. Acad. Nat. Sci. Phila., 1881, p. 118; Jordan, Proc. U. S. Nat. Mus., 8, 1885, p. 390; Jordan and Evermann, Bull. U. S. Nat. Mus., 47, pt. 3, 1898, p. 2412.

Because of their entire inconstancy, and because of the high probability that the colors can be altered by the individual, the several color-phases of *Apodichthys flavidus* should receive no nomenclatorial recognition, even as varieties or races. The names thus involved as synonyms of *flavidus* are *virescens*, *sanguineus* and *inornatus*. Although hitherto not suspected, it can now be certainly stated that *Apodichthys univittatus* Lockington is based on the young of *A. flavidus*, as specimens of similar size from California correspond sufficiently well with the type-description of that nominal species; the occurrence of the species at the supposed type-locality of *univittatus* (the Gulf of Cali-

fornia) is improbable in the extreme, as none of the northern blennies are definitely known to range so far to the south, and as the present species has never been recorded from the coast of Southern California nor the outer coast of Lower California. The southernmost locality at which we have taken the species is just south of Point Arguello, on the outer coast of Santa Barbara County, California.

XERERPES Jordan and Gilbert

Xererpes fucorum (Jordan and Gilbert)

Apodichthys fucorum Jordan and Gilbert, Proc. U. S. Nat. Mus., 3, 1880, pp. 139, 265; 3, 1880 (1881), p. 454; Jordan and Jouy, *ibidem*, 4, 1881, p. 4; Jordan and Gilbert, *ibidem*, p. 64; Bean, *ibidem*, p. 263; Bull. U. S. Nat. Mus., 16, 1883, p. 770; Jordan, Rept. U. S. Comm. Fish and Fish., 1885, p. 910; Eigenmann and Eigenmann, Ann. N. Y. Acad. Sci., 6, 1892, p. 357.

Xererpes fucorum Jordan and Starks, Proc. Cal. Acad. Sci., (2) 5, 1895, p. 846; Jordan and Evermann, Rept. U. S. Comm. Fish and Fish., 1895 (1896), p. 473; Bull. U. S. Nat. Mus., 47, pt. 3, 1898, p. 2413; Jordan, Guide to the Study of Fishes, 2, 1905, p. 512; Starks and Morris, Univ. Cal. Publ. Zool., 3, 1907, p. 239; Starks, Ann. Carn. Mus., 7, 1911, p. 199; Metz, Ann. Rept. Laguna Mar. Lab., 1, 1911 (1912), p. 57, pl. 2, fig. D, text figs. 28, 29; Halkett, Check List Fishes Canada, 1913, p. 110; Kincaid, Annotated List Puget Sound Fishes, 1919, p. 41; Bean and Weed, Trans. Roy. Soc. Canada, (3) 13, 1919 (1920), p. 81.

Exerpes fucorum Gilbert, Rept. U. S. Comm. Fish and Fish., 1893 (1896), p. 470 (generic name misspelled).

Xererpes fucorum ranges southward as far as Point Loma, San Diego County, California.

ULVICOLA Gilbert

Ulvicola sanctae-rosae Gilbert and Starks

Ulvicola sanctae-rosae Gilbert and Starks, in Gilbert, Proc. U. S. Nat. Mus., 19, 1896, p. 455, pl. 55, fig. 2; Jordan and Evermann, Bull. U. S. Nat. Mus., 47, pt. 3, 1898, p. 2413; Starks and Morris, Univ. Calif. Publ. Zool., 3, 1907, p. 239; Osburn and Nichols, Bull. Am. Mus. Nat. Hist., 35, 1916, p. 179; Fowler, Proc. Acad. Nat. Sci. Phila., 75, 1923, p. 294 (in part).

This species is definitely known only from Santa Rosa and Santa Catalina Islands off southern California and Guadalupe Island off Lower California. Fowler's San Pedro record (*l. c.*,

1923, p. 294) we find, on reëxamining the material, to have been based on a species of Lycodapus, a very different genus.

SCYTALINIDAE

SCYTALINA Jordan and Gilbert

Scytalina cerdale Jordan and Gilbert

Scytalina cerdale Jordan and Gilbert, Proc. U. S. Nat. Mus., 3, 1880, p. 266; 3, 1880 (1881), p. 454; Jordan and Jouy, *ibidem*, 4, 1881, p. 3; Jordan and Gilbert, *ibidem*, p. 65; Bean, *ibidem*, p. 262; Jordan and Gilbert, Bull. U. S. Nat. Mus., 16, 1883, p. 790; Jordan and Starks, Proc. Cal. Acad. Sci., (2) 5, 1895, p. 849, pl. 104; Jordan and Evermann, Rept. U. S. Comm. Fish and Fish., 1895 (1896), p. 481; Bull. U. S. Nat. Mus., 47, pt. 3, 1898, p. 2454; pt. 4, 1900, figs. 849, 849a, 849b; Jordan, Guide to the Study of Fishes, 2, 1905, p. 519, fig. 471; Starks, Ann. Carn. Mus., 7, 1911, p. 212; Gilbert and Burke, Bull. U. S. Bur. Fish., 30, 1910 (1912), p. 89; Regan, Ann. Mag. Nat. Hist., (8) 10, 1912, p. 276; Halkett, Check List Fishes Canada, 1913, p. 113; Kincaid, Annotated List Puget Sound Fishes, 1919, p. 43, fig. 101.

Scytaliscus cerdale Jordan and Gilbert, Proc. U. S. Nat. Mus., 6, 1883, p. 111; Jordan, Rept. U. S. Comm. Fish and Fish., 1885, p. 914.

Heretofore this most remarkable fish, the only species of its genus and family, has been known from only two localities, Waada Island, in Neah Bay, near Cape Flattery, and Agattu Island, one of the Aleutian chain. We have taken it at Fort Bragg, in Mendocino County, and at Point Lobos and Gorda in Monterey County, California.

OPHIDIIDAE

OTOPHIDIUM Gill

In 1916 [15] we indicated that the supposedly peculiar structure of the air bladder in *Otophidium taylori* (the type-species of Chilara) is not constant. Therefore we suppressed the genus Chilara, synonymizing it with Otophidium.

Two species occur in California, separable as indicated below:

a[1]. Gill-rakers moderately long and slender
- b[1]. Gill-rakers on lower limb of outer arch 4 to 6, usually 5; body at comparable sizes decidedly more robust (depth 5.65 to 8.0); adult of entirely plain coloration. . . . .*Otophidium scrippsi*

[15] Hubbs, *Publ. Univ. Calif. Zool.*, 16, 1916, p. 166.

b². Gill-rakers on lower limb of outer arch 7 to 9; body more attenuate (depth 8.0 to 11.2); adult conspicuously spotted with brown. . . . . *Otophidium taylori*

Otophidium scrippsi Hubbs

?*Chilara taylori* Snodgrass and Heller, Proc. Wash. Acad. Sci., 6, 1905, p. 420 (record based on a specimen doubtfully referred to *O. scrippsi* by Hubbs, 1916).

Chilara taylori Starks and Mann, Univ. Calif. Publ. Zool., 8, 1911, p. 16 (record based on type of *O. scrippsi*).

Otophidium scrippsi Hubbs, Univ. Calif. Publ. Zool., 16, 1916, p. 166, pl. 20.

Range: Coasts of southern California and Lower California, from Long Beach to Cerros Island.

This species has heretofore been known definitely only from the type, dredged in 73 meters near Cerros Island, off the coast of Lower California, and doubtfully from a partially digested specimen from the stomach of a tunny taken at Tagus Cove, Albemarle Island, Galapagos. We have now at hand ten specimens taken by the California State Fisheries Laboratory, at four stations, in shallow water (2.5 to 15 fathoms) in the general vicinity of Long Beach, California.

This new material shows the species to be quite variable in several respects. Head, 4.7 to 5.15 in length to caudal; depth, 5.65 to 8.0 (the body becoming more robust with age); eye, 3.6 to 4.5 (decreasing in relative size with age); snout, 4.2 to 5.0; upper jaw, 2.3 to 2.5; gill-rakers 4 to 6, usually 5, on lower limb of outer arch; caudal deeply emarginate, truncate or rounded; pectoral, 1.75 to 2.1; longest pelvic filament, 2.05 to 2.4.

Otophidium taylori (Girard)

Ophidium taylori Girard, U. S. Pac. R. R. Surv., 10, pt. 4, 1858, p. 138.

Chilara taylori Jordan and Evermann, Bull. U. S. Nat. Mus., 47, pt. 3, 1898, p. 2489.

Otophidium taylori Hubbs, Publ. Univ. Calif. Zool., 16, 1916, p. 166.

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SOME BEHAVIORS OF *VAMPYRELLA LATERITIA* AND THE RESPONSE OF SPIROGYRA TO ITS ATTACK

FRANCIS E. LLOYD

THE responses of higher plants, at least in their morphological aspects, to the attack of various animals are so well known in general, that we need no persuasion that the behaviors of lower forms of vegetation under similar condition are well worth investigation. Nevertheless information in this field bulks but meagerly in the few texts which deal with plant pathology. It happens also that some animalcules have so nice a technique in the manipulation of their food plants (not to speak of their animal prey) that their voracity may well be made a virtue by regarding them as microdissectors of supreme skill. It was with this thought that the present study was begun. Such contributions here added to our knowledge of the animal *Vampyrella lateritia* may be regarded as a byproduct of the original effort to determine the nature of the reactions of the food plant, in this case *Spirogyra Weberi.*

Habitat. — Dense mats of the plant were found in the deeper portions of shoreway pools along the banks of the St. Lawrence River, at Verdun, near Montreal. Conjugation was in progress at the late date of collection, late in October and early in November. The material, after being in the laboratory in aquaria for some days, was found to be infested as usual with a great many organisms, among which Vampyrella was sufficiently abundant to enable me to follow its behavior in many cases, and to produce a motion photomicrograph recording it. Later in the winter (January) another aquarium was found to contain a number of resting individuals which enabled me to determine accurately the form and number of membranes, their disposition,

etc., occurring under a large *quasi*-natural degree of freedom. When kept with an abundance of living Spirogyra [1] under a cover-slip on an ordinary slide, in a moist chamber, and with water added from time to time, the animal was found to behave quite naturally even for several days. Under these circumstances the resting forms were apparently not quite normal in form.

Morphology. — Viewed from above — the animal is assumed to be walking on the slide — it appears almost spherical. Regarding the limb, however (I watched especially the forwardly directed), one may observe a certain agitation of the surface, due to the repeated bursting of numerous contractile vacuoles, I believe.

From the whole surface there project into the surrounding medium numerous slender tapering ("filiform") pseudopodia, the length of which may equal fully three diameters, considerably longer, therefore, than stated by Hoogenraad (1907). The filiform pseudopodia laterally placed attain the greatest length, and, during forward movement, always display an evident degree of curvature, this being rather pronounced and confined to the region closer to the body. These curvatures (Pl. XXV, Fig. 1) indicate strain normal to the axes of the pseudopodia and are undoubtedly due to the effort to move the body forward by the aid of these organs. It is evident from their degree of persistence that the axis of motion of the body remains laterally steady; that is to say, there is a definitely steadied axis during motion. When seen in movement in side view, the under surface is more evidently agitated, blunt pseudopodial enlargements being extended and withdrawn (Pl. XXVI, Figs. 1–5). Indeed, more especially in crowded situations, or just after feeding, the whole organism partakes of such distortions. During forward movement the antero-posterior axis remains steady, displaying only slight oscillations in the sagittal plane. There is, therefore, no rolling and the oral surface seems to be constant [2] in position. There is sometimes a rather large central vacuole eccentrically

[1] West (1901) records *V. lateritia* feeding on Mougeotia.

[2] My photographs 15–17, Plate XXV, indicate some structure which I am unable to explain, but which is possibly connected with the mouth.

placed and the centre of it lies behind the centre of the organism during forward movement (Pl. XXV, Fig. 1).

Whether these facts consist with the idea that this organism, Vampyrella, is homaxial (according to Hoogenraad) depends, therefore, upon whether it is based on morphology in a very strict sense or not. Since such animals have little to boast of in the form of permanently postured structures, it seems more proper to validate or invalidate the idea in question on physiological grounds, in which case I prefer to regard Vampyrella as bilateral. It is certainly different in this regard from some of its near relatives which exercise the virtue of patience in waiting for their prey to come to them. Vampyrella is a lively animal and continually on the hunt if hungry. Whether the polarity I attribute to it is unalterable or can change from time to time requires further study. It will be recalled that Actinosphaerium and Vampyrella may assume a caterpillar-like form and movement (I have myself observed it in the former) in which condition some such sort of temporary polarity is evident.

The ambulatory movements, when the animal is viewed laterally, are somewhat peculiar and worthy of note, in that the animal, in moving forward, does not do so in one plane, but performs a series of cycloidal curves as if he were repeatedly vaulting over some unseen obstacles. This seems to be the effect of its manner of using its walking pseudopodia, but I have to confess to failure of sufficient observation to enable me to venture an explanation. During progress there is frequent slight change in shape (Pl. XXVI, Figs. 1–5).

In addition to the filiform pseudopodia, there are also short, acute ones, and "pin-rays" (Leidy, 1879). During feeding, the filiform disappear, except such as may be retained at the edge of the body near the food plant. On the other hand, I have observed pin-rays to be plentiful and quite constant at this time, my motion photomicrographic record having registered them quite clearly (Pl. XXVI, Figs. 8–12; Pl. XXVII, Fig. 4). In the motile condition they are more rapidly protruded and withdrawn. They are more numerous in the "side opposite to the direction of movement," to quote Leidy, who thought this to be the case.

Leidy's observations are, therefore, correct, though at variance with those of authors of an earlier date. Short acute rays are also to be seen while feeding, indeed may be the only sort present. On the other hand, there may be no pseudopodia at all present (save only at the appressed margin), especially during the later phase of the feeding time, the contour being smooth (Pls. XXVI–XXVII). Any of the pseudopodia (not only the filiform as Leidy thought) may fork (Pl. XXVII, Fig. 4), but do not anastomose (Hertwig and Lesser; Leidy). The forking is more frequent in the short ones when the animal is attacking or leaving the food plant. While there is considerable rapidity in their extension and retraction during walking, any one may persist for several minutes during feeding (Pl. XXVI).

The resting condition (Pl. XXV, Figs. 9–17) consists of a condensed slightly reniform body, the interior of low visibility by transmitted light, and clothed with two membranes (Cienkowski). The inner invests the animal tightly and is quite smooth and colorless; the outer (velum) also is colorless, but loose and veil-like, and adheres by the oval surface to the supporting substratum, usually a Spirogyra filament. Both membranes afford a cellulose reaction, not one only, as Cienkowski has held. The reaction is very pronounced and takes place more readily in these membranes than in the walls of Spirogyra under observation in the same field; that is, they yield more readily to the hydrolyzing action of sulphuric acid than Spirogyra cellulose and may be regarded, therefore, as belonging to the hydrocelluloses, though they do not give the blue reaction with iodine alone (amyloid reaction), as do some plant membranes.

When the animal passes into the resting condition in the narrow confines of the film of water between the glass slip and cover, its shape is less uniform in various individuals and more rounded than when it has free space as in an aquarium. I base this statement on a comparison of several which passed into this state under my eye, and many others in like situation, with individuals later found by me in an aquarium originally stocked with material from the same locality and which I have no doubt

were of the same species. During the earlier portion of the resting period, when a hyaline border is still distinctly apparent (Pl. XXV, Figs. 13–14), there may be seen numerous contractile vacuoles just beneath the entire surface of the body, save perhaps a basal area. Leidy observed vacuoles in the hyaline border of the active animal, but their contractile character has not been apprehended. These vacuoles attain various sizes, requiring 40 to 70 seconds to grow and 3 to 5 to discharge.

The speed of discharge is low as compared with that of contractile vacuoles in Spirogyra, Arcella, Amoeba and Actinophrys, but I have observed on occasions a much slower discharge in Amoeba, while the time occupied may extend to five or six seconds in Spirogyra. We may infer that slow discharge is due to high viscosity of the cytoplasm, and it is not surprising that in the condensing state of Vampyrella the viscosity should be high — I have observed the same in condensing gametes of Spirogyra (Lloyd, 1924, 1926 *a*, *b*).

The color of the organism varies from a dirty yellow to deep red-yellow orange. The depth of color increases with the progress of digestion of the chloroplasts of the food plant (Cienkowski, 1865). The occurrence of this pigment in other forms allied to Vampyrella, when they have fed on green plants, has been noted (see Hoogenraad). The pigment, together with chlorophyll, is soluble in alcohol. In the absence of final proof it may be called a carotinoid. The pigment *in situ* is not diffuse (Hertwig and Lesser), but in solution in minute vesicles which appear as black granules when photographed by blue transmitted light (Pl. XXV, Fig. 17). As it does not leach out from the dead animal kept for two months in water, we may infer it to be dissolved in lipoid.

In addition to the pigment vesicles, there are others of similar size containing matter to be regarded as waste which is thrown out from time to time. During prolonged feeding this waste is ejaculated from the whole free surface of the body on several occasions and remains for some time as a cloud of granules of various sizes overlying the surface (Pl. XXV, Figs. 4, 9) and entangled among the pseudopodia if present. It finally dis-

appears, though some of it may cling to the surface of an emptied Spirogyra cell with sufficient tenacity to permit of being photographed (Pl. XXV, Fig. 8). The process of ejaculation may be pictured as a simultaneous bursting of a lot of vesicles (which is but another name for minute vacuoles). When this happens, the whole animal seems to contract slightly. This discharge can occur whether pseudopodia are present or not. When they are present, the granules after discharge pass out between them, thus affording an exact picture of what Gurwitsch — and Nicolas and Stricht before him — believed to occur during excretion from kidney epithelium, without destroying or permanently disturbing the cilated layer. Gurwitsch indeed compared the behavior of the kidney epithelium cells with that in the protozoa, maintaining that in both cases it is by the activity of contractile vacuoles that the excreta are thrown off. Figure 9, Plate XXV, shows an animal just after a copious ejaculation.

Behavior pertaining to feeding. — The wanderings of the animal appear erratic in the matter of direction until he comes into the vicinity of a Spirogyra [3] filament. Approaching it, he may walk along it or come to rest on it immediately. Having decided on a point of attack, the animal becomes dome-shaped, the flat base lying next to the filament. He then flattens to this, spreads about it say three quarters of the circumference and becomes closely appressed. During the progress of taking a stance he assumes a variety of shapes, often maintaining a distinctly irregular form during the actual feeding process. Any specific description can apply, therefore, to only one individual, as when Hoogenraad says that the animal becomes "triangular" (his Figure 6). The usual course of events is somewhat as I show in my rough sketches, reproduced without later amendment (Text Fig. 14). After flattening out, anchoring pseudopodia extend from the now evident margin of the body, long ones more or less confluent at their bases extending lengthwise along the filament, shorter ones from the rest of the edge of the animal. The outer ends are attached to the surface of the filament, but may

[3] If he finds the cell dead or empty, he soon discovers the fact and promptly moves away.

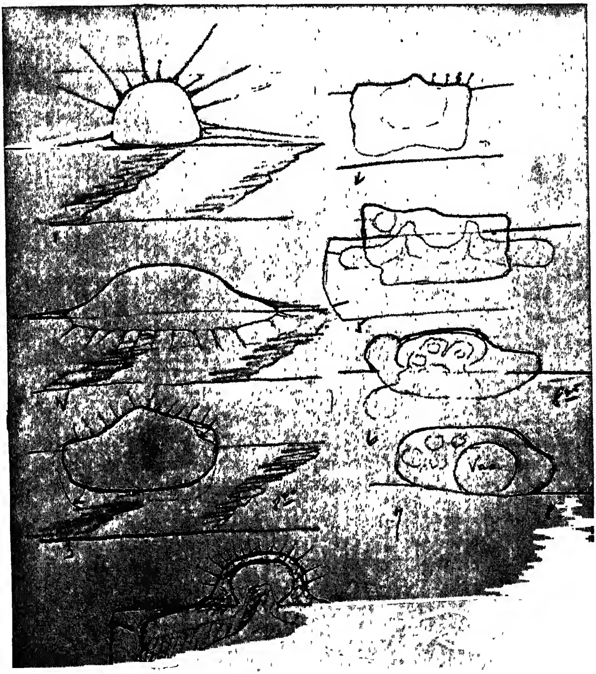

FIGURE 14

Series of sketches taken without change from note book record. Figures 1 to 7 show observed changes in form, with indications of the character of the pseudopodia. Figure 8, an individual in which the form of the receptive vacuole is indicatory of internal buttresses. Compare with Figures 5–8, Plate XXVI.

for greater purchase during feeding be changed, or new ones be extended in some other direction and attached to another filament or other mass within reach. When it is struggling to master a difficult situation, determination seems to be writ large in the movements of readjustment made to gain a satisfactory stance (Text Fig. 15).

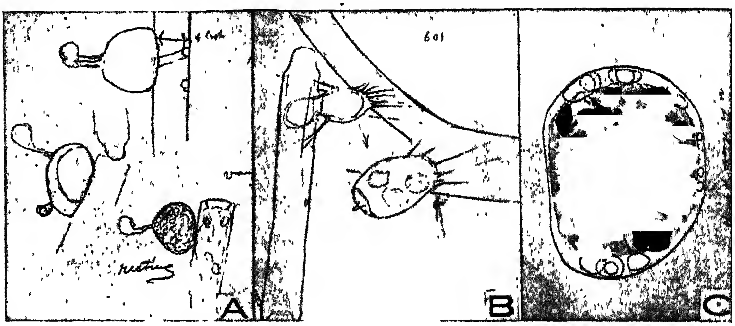

FIGURE 15

A. Eruption of material from apical region of an animal contracting when entering the resting condition. Note that disarticulation of the Spirogyra cell ensued, together with change (death) in chloroplasts and cytoplasm.
B. Alteration of stance, and final swallowing.
C. Sketch showing position, shape and size of contractile vacuoles during early phase of resting condition.

When settled down as an appressed saddle-like plaster, the animal at once begins the task of getting at the contents of the cell on which he rests. This consists in the digestion of the wall to form an oval opening (Cienkowski). Cienkowski correctly interpreted what he saw, not finding any solid relic within the animal. The edge of the opening shows clearly that digestion is the means employed (Pl. XXV, Fig. 8). It is remarkable that the application of the enzyme is quite definitely localized, but nothing in the form of vacuoles or any other feature evidently connected with the secretion of this enzyme can be detected as far as my observation goes. This animal does not send any process into the cell, *contra* West.

The turgor of the normal Spirogyra cell is produced by the

cell sap, which has a total concentration of solution with an osmotic pressure of *ca.* 10 atm. With the softening of the wall by digestion, the initial release of this pressure is evident in a dome-shaped projection of the softened area into the animal (Pl. XXVII, Fig. 4) and in the bellying in of the transverse walls at the ends of the attacked cell. Their maximum concavity is reached at about the moment when the hydrolysed area of the wall at the point of attack has become sufficiently softened to give way under the turgor pressure of the cell (Pl. XXVI, Fig. 7; Pl. XXVII, Fig. 5). This happens suddenly and at the moment the sudden release of pressure results in the disarticulation (abjection) of the attacked cell from the adjoining cells of the filament. In *Spirogyra Weberi*, which has replicate end-walls, the disarticulation is usually quite violent and may be sufficient to hurl the animal, attached to the dismembered cell, quite out of position (Pl. XXVI) and often to some distance. This does not disturb the equanimity of the animal in the least. The disarticulation is accomplished in from one to five minutes, so that the digestion of the wall must occupy less time than this. This response of the plant seems to be purely mechanical, the mutual pressures of the end-walls being sufficient to rupture the common wall in the immediate vicinity. It had been held by some authors previous to West (1901) that the animal attacks the cell by breaking the filament at the joints, but West confirmed Cienkowski's observations, which are as here set forth.

It should be noted that the disarticulation of the attacked Spirogyra cell may occur just previous to the bursting of the hydrolysed area, or just afterward. In the former case the end-walls of the attacked cell are not outwardly distended (Pl. XXV, Fig. 5), and the animal is distended by the full amount of water producing extension of the Spirogyra cell-wall. In the latter case, the bulging end-walls take up some of this volume and the animal thus suffers less distention (Pl. XXVI, Fig. 8). It is obvious that the absolute sudden distention of the animal will depend further on the total volume of the attacked cell. As for the animal, the sudden rush of cytoplasm and sap, chiefly the latter, quickly distends him by forming in his middle a large vacuole

filled with sap. That he is not blown off the filament is due to the firm marginal adhesion and to the fact that with the expulsion of about 2 to 4 per cent of the volume of the cell the whole distentive force is discharged. Even this much sap may be sufficient to make the animal appear distinctly bladdery (Pl. XXVII, Fig. 6). Into the cavity thus newly formed the contents of the Spirogyra cell, first the chloroplast, then the cytoplasm, begin slowly to pass.

During the hydrolysis of the wall at the point of attack a change in the physical properties of the chloroplast in the vicinity of the outwardly distended wall becomes apparent in that it begins to swell. That this swelling always commences before rupture takes place I cannot affirm, but that it may do so there is no doubt (Pl. XXVII, Fig. 4).[4]

The first indication that ingestion has begun is the approach of one or two turns of the chloroplast in the immediate vicinity of the opening toward it, as if being caught up. The chloroplast continues to swell (Pl. XXVI, Fig. 7) and this effect now travels rapidly toward its ends till the whole begins to assume a form of minimal area of surface. Thereby it becomes sausage-shaped and greatly distended, having precisely the form of a blown-up sausage skin. The turns disappear. My notes tell me that in half a minute the swelling response travelled from the immediate region of the animal, where it involved three turns of the chloroplast to the end of it — a distance roughly of about 100 microns in 30 seconds. But the value of this datum, if correct, is questionable until we know the nature of the response in swelling. We may say at least that at the point where the animal is exerting a pull on the chloroplast there are forces which in life resist the tendency toward the assumption of minimal area of surface by the chloroplast. Upsetting of the physiological equilibrium in one place may bring a local change, say of surface tension or other conditions, which may be propagated along the chloroplast.

[4] I observed in one instance that the mere act on the part of Vampyrella of settling down on a filament of Spirogyra for the resting period was sufficient to cause the chloroplast to change.

One thing I venture to believe we may be sure of, that it is not merely the mechanical pull on the chloroplast which initiates the swelling, since the tension on the chloroplast of the male gamete occurs during conjugation without being followed by any changes in it. Further, I have observed that during feeding the biting of the chloroplast by the rotifers and the attack of some fungi (perhaps not all) are not followed by swelling, while on the contrary mechanical disturbance (pressure of the cover-glass on crossed filaments) can induce fluidity and possibly swelling. Under such circumstances the action is irregular and expressed rather in the beading off of the chloroplast. The action under the attack of Vampyrella, especially in view of the fact that swelling may occur before the cell is ruptured, is much more like that of salts as described by Scarth and as seen by myself on the penetration of salts after narcotics (Lloyd, 1924), and is moreover very uniform, with the effect of tearing away the chloroplast from the cytoplasm and setting it more or less free in the sap-cavity. This possibly permits the direct action of the salt of the sap upon the chloroplasts, which gives the condition for swelling. In this case a condition of permeability for salts is assumed for the chloroplast. But this can hardly be the case, since the chloroplast does not merely round off but increases in volume.

The release of the chloroplast from the wall layer of cytoplasm is accompanied by a pulling movement, whereby it is drawn into the interior of the receptive vacuole — as I shall call it — of the animal. Here the chloroplast suffers change of semi-permeability, and in consequence loses bulk and beads off into separate lumps. When this movement has brought the ends of the chloroplast within a short distance of the exit into the receptive vacuole, the cytoplasm — which forms a tube lining the cell-wall — begins to move; and it is now evident that this is the more difficult part of the task. To state, even approximately, what conditions create this difficulty requires more knowledge of the articulation of the cytoplasm with the cell-wall than we have; but if, as we are growing to believe, the cytoplasm penetrates the cell-wall — that the wall is a part

of the living cell and not merely a passive shell about it — then we have to contemplate the fact that there is not merely the friction of the cytoplasm on the wall, which should be small since there is now no turgor pressure, but the further condition, that the cytoplasmic extensions from the so-called ectoplasm into the wall must be torn across or drawn out. That such extensions do exist was long ago shown by F. O. Bower (1883); they can be seen when the cell is plasmolysed, a matter of everyday laboratory observation too little reflected upon. If this be the condition, then we can very well see what sort of job a Vampyrella has to pull the "primordial utricle" out of its position. Observation of the matter substantiates the impression that it offers considerable resistance to the pull, leaving its position long after the chloroplast has been dislodged. The fact of normal adhesion to the end-wall is actually made visible as the end of the primordial utricle leaves it, for it often sticks to this with sufficient tenacity so that a thick string of cytoplasm is drawn out at last to break away (Pl. XXVI, Figs. 13–15). The rate of rounding off indicates normal, comparatively low viscosity. When almost all the cytoplasmic utricle is withdrawn there may still remain fine threads indicating adhesions. At no time is there any haustorium projected by the animal into the plant cell during feeding.

As soon as withdrawal is complete, the animal closes the receptive vacuole and begins to move from the exhausted cell, and now may be seen the hole which he made. The margin of this is clean-cut, evidence of a sharply localized application of the agent of hydrolysis. The whole period of attack, from first contact to completion of withdrawal of the plant cytoplasm, occupies about 20 minutes. The long period recorded by West seems to have been a case of failure. Being voracious, the animal passes from cell to cell, repeating the operation until he becomes replete. When his appetite is satisfied, he will be seen to approach and settle down upon a filament as if to feed once again, but ceases after becoming dome-shaped, condenses still further and passes into post-prandial lethargy. The outer membrane is secreted before complete condensation while he is dome-shaped.

The second membrane closely investing the later rounded-off body is secreted inside this. In shape the resting animal is very smoothly and regularly elliptical (Hoogenraad), but the relative length of the major and minor diameters may vary. I have not seen it spherical, as Hoogenraad reports. So far as his Figures 7–9 are intended to convey any information relative to the structure of the resting form, I find difficulty in understanding them. I have seen nothing like them.

In the initial period of rest the body is loaded with masses of food which, while not spherical, are more or less rounded (Pl. XXV, Fig. 15), each occupying a food vacuole, formed of course by receiving the beaded-off masses of chloroplast — we may suppose also accompanied by cytoplasm, but the chloroplast at all events we can see — into the cytoplasm from the receptive vacuole. This takes place quickly after the meal has been finished. I noted distinctly on one occasion that the receptive vacuole was empty of solid matter in less than two minutes after the last portion of the chloroplast was withdrawn. The receptive vacuole disappears completely and the food-filled vacuoles of a plethoric individual block the light, so that it is difficult to photograph the condition (Pl. XXV, Fig. 13). In one individual which I watched from time to time for several days (Pl. XXV, Figs. 13–17), there persisted during at least the first half-day a broad hyaline margin which was thicker at the ends of the reniform body than elsewhere. In this zone I was able to observe the formation and disappearance of vacuoles which turned out to be contractile vacuoles. Those in the broader portion of the hyaline margin were larger than those elsewhere and more numerous. But they were to be seen everywhere (Text Fig. 15 *c*). They were sometimes exceedingly small, but once seen could not be mistaken, and were observed by other members of my laboratory staff. Having once seen these, I looked for them in motile animals and found evidence that they are here also in numbers, small in size and frequently bursting. If one watches the hyaline margin of a moving animal, it may be seen to erupt here and there continuously. There is little doubt that the eruption is due to the breaking out of small

contractile vacuoles. Previous investigators have acknowledged failure to observe them. The condensation of the resting condition of Vampyrella is evidently due to their activity, and here they have all the appearance of the contractile vacuoles in the conjugating gametes of Spirogyra, except that instead of becoming very nearly spherical, they are compressed between the ectoplasm and the granular endoplasm, and hence are more or less flattened (Text Fig. 15 *c*).

That in the feeding motile animal there is a rapid excretion of water is certain. I calculate that one which consumes four cells consecutively — and I saw one do this — will have to do away with thirty to forty times his original bulk of food and drink. To be sure the whole of the water content of the cytoplasmic utricle is not engulfed in his maw, but so much as to make him of distinctly greater volume. This volume can be seen to be reduced by two thirds during a few minutes perambulation following a meal (Pl. XXVII, Figs. 12–18). This condensation I attribute to the great activity of many small contractile vacuoles as stated above. The obvious alternative would be to assume loss of semi-permeability, or none, but this would not be admitted in the presence of such contrary evidence as the growth and maintenance of solutes in food vacuoles, and of a central vacuole not infrequently seen.

During the course of the first day, the hyaline margin of the earlier period of the resting condition largely disappears and the vacuolar activity is reduced to a minimum, or perhaps ceases entirely. The membranes are now complete. There may be observed constant cyclosis in minor amplitude. In the two figures (Pl. XXV, Figs. 13, 14) during a period of less than 15 minutes, evidence both of the rearrangement of food vacuoles and also of contractile vacuoles in the "hyaline border" is to be seen.

As one watches the food particles for several days their reduction in size becomes apparent (Pl. XXV, Figs. 13, 17). Their digestion reduces their size, but in the place of solid material a sap arises which maintains the food vacuoles approximately at their original size, but now quite spherical. The increase of red-

orange pigment during this period is noticeable, as I have already pointed out above, but the "immediate" loss of green color by the ingested chloroplast, as recorded by Hoogenraad, was not observed by me. Indeed, the green color persisted for days, as long as undigested fragments of the chloroplast were visible, albeit the color was changed from the bright translucent hue of the living organ to a darker and opaque one, one which is observed in chlorophyll on standing.

The case most similar to Vampyrella in regard to the disparity of size between hunter and prey and to the mechanics of devouring is, so far as I am aware, that of *Didinium nasutum*, an account of which has been given by Mast (1908–9). Didinium is a ciliate which can swallow a Paramecium ten times its own volume, so that when the act, which occupies one to three minutes, is completed, "the Didinium forms a mere film over the Paramecium." Didinium differs, however, from Vampyrella in being provided with a seizing organ by which it becomes attached to its prey, and which is retracted as an early act in the process of swallowing. It is, however, but preliminary to the major act of engulfing the prey by (*a*) suction produced by active expansion of the body; (*b*) extension of the oval opening over the prey; (*c*) contraction of the mouth when the prey is nearly swallowed. On first reading Mast's account one tends to attach more importance to the difference noted above, viz: the possession of the "seizing organ" which, after effecting attachment, seems to me to be rather of importance, by retraction, in serving as a fulcrum to enable the Didinium to apply its mouth to suction. Mast, in commenting upon the matter, remarks: "The most marvellous phenomenon in this whole process is the movement of the seizing organ and the active spreading out of the substance of the Didinium in the form of a sac-like structure. I know of no other organism with the possible exception of Hydra that has the power of such extreme extension." No less, but, it seems to me, rather more marvellous is the ability of a unicellular organism with apparently no skeletal structure to exert suction, for which Mast affords good evidence. In this chiefly lies the similarity between Didinium and Vampyrella.

The latter, however, carries off the prize in the eating contest. Mast calculates that a Didinium (which does not confine itself to Paramecium) can engulf a volume twelve times as great as its own in twenty-four hours; Vampyrella can do much better, taking in thirty to forty times its volume in 90 to 100 minutes!

Attending particularly to the mechanism of suction, we may note that there is evidence of a sort of mechanism in Vampyrella which enables us to visualize in some degree a structure commensurate with the task. This is to be seen in the Figures 5–10, Plate XXVII, in which radial rib-like thickenings are apparent. My notes contain a sketch which indicates a similar structure in another animal (Text Fig. 14, No. 8), but I made it before appreciating the nature of the problem. These seem to mean that the receptive vacuole is an arch-supported dome and not a mere smooth-walled cavity. Withdrawal of the ribs by radial contraction would at once furnish additional material for extension of the dome and a framework for its support if only we assume a higher degree and extent of viscosity and greater elasticity to characterize the inner membrane. As in Didinium, collapse may occur (Pl. XXVII, Fig. 8), or at least, in my motion picture record, it seems to occur.[5] Further observation will be required to show whether this description fits the facts, but in the meantime it will be noted that this arrangement permits expansion of the dome by *contraction* of the supporting ribs. When such activity is marked, there are no pseudopodia, this probably being correlated with a high viscosity of the ectoplasm.

The closing phase of swallowing the food seems to fit Mast's description for Didinium. This was especially apparent in one instance (Text Fig. 15 *b*). On this occasion the animal evidently had a tussle to pull out the last piece of the Spirogyra cytoplasm, and in order to improve his stance he put out pseudopodia, reaching backward (in a manner of speaking) to another filament. Having got a new and more suitable grip, he was able to pull

[5] Unfortunately there is a few seconds' hiatus in the continuity of the film between Figures 7 and 8, Plate XXVII, so that I am not sure of the time factor. There is no doubt, however, that there was rather rapid if not sudden decrease in size, due either to collapse and escape of water by leakage or by rapid vacuolar discharge.

the stuff out, and I then saw the mouth closing on the food mass. The lower sketch shows the appearance just before final closure.

In his description of Didinium, Mast says nothing of the reduction of size after a meal. The animal has one contractile vacuole. In Vampyrella the rapid reduction in size is a most notable feature. The time occupied for this in the animal shown on Plate XXVII, Figures 12–18, was five minutes, during which the volume was reduced by two thirds. There can be little doubt that this is accomplished by an extraordinarily great activity in water discharge by the means afforded by contractile vacuoles which I have seen even in the thin wall of a turgid animal while devouring a Spirogyra cell. This rapidity of water excretion impresses one with the probable importance of contractile vacuoles in glandular cells such as those of the kidney. The argument of Gurwitsch (1902), cited above, here finds remarkable support.

SUMMARY AND COMMENT

1. The Vampyrella observed fed exclusively on slender species of Spirogyra (*S. Weberi, longata*). It could be kept under observation for several days on a slide, under a cover-glass, in a moist chamber.

2. It exhibits functional polarity (*a*) in the disposition of pseudopodia in walking; (*b*) in the constancy of position of its axes; (*c*) in the (probable) constancy of the place at which the excretion of a cellulose-dissolving (and other ?) enzyme, and at which also the mouth appears.

3. The resting animal is reniform (or nearly so) and exhibits some degree of polarity. It is invested by two cellulose membranes, the inner firm and closely fitting; the outer (velum) loose and draping. The latter attaches the animal to the substrate, usually a Spirogyra filament.

4. After coming to rest on a suitable Spirogyra cell, it spreads out on it more or less, and by hydrolysis a definite oval portion of the cell-wall is removed. This, during the process of hydrolysis, bulges into the animal until it bursts under the turgor pressure of the attacked cell. An inrush of water causes sudden

expansion of the animal, wherein a vacuole is thus set up. This is the receptive vacuole.

5. The lining of the receptive vacuole is probably ectoplasmic. It is not a mere spherical vacuole; there is evidence that the wall is folded into meridional ridges forming interior buttresses. A mechanical condition is thus supplied by which suction may be applied.

6. Usually the whole content of the Spirogyra cell is ingested. The volume of the animal thereby attains a net value three times greater (at least) than the original volume. That the whole of the sap is taken in is doubtful.

7. After ingestion is completed, the mouth closes over the mass. In the meantime more or less of the Spirogyra protoplasm and chloroplast is engulfed in the cytoplasm, and then rests in fragments in food vacuoles. The receptive vacuole gradually disappears.

8. During and after feeding there is great contractile vacuolar activity, whereby water is excreted. The animal in this way resumes approximately its original volume within a few minutes, when it may attack another cell. The contractile vacuoles are numerous and minute.

9. During feeding there usually occur active contractions of the body accompanied by the simultaneous ejection of minute granules which for a time remain as a cloud overhanging the surface of the animal. I regard this material as fecal matter.

10. During feeding the pseudopodial activity gradually subsides. First the filiform pseudopodia are withdrawn (except those used for anchoring). The short ones, especially the "pin-head" sort, persist more or less, but usually disappear during the later period of ingestion. The whole operation of attack and feeding occurs in approximately twenty minutes.

11. An attacked Spirogyra cell-wall suffers hydrolysis at the point of attack. Since it has two chemically different membranes to be hydrolysed, two kinds of enzymes may be inferred to be secreted by the animal. When hydrolysis ends in bursting, the cell suffers abjection if the contingent cell or cells are normal. This fragmentation appears to be mechanical.

12. During this period and before abjection, the chloroplast of the attacked cell begins to swell, beginning in the region near the point of attack. This organ continues to swell, at length beading off, assuming forms with minimal area of surface. In the swollen condition the chloroplast is hollow and its interior is traversed by ridges and trabeculae.

13. The withdrawal of the chloroplast is much more rapid than that of the cytoplasm (the "primordial utricle"). This and its manner of separating from the end-walls indicate that there is a normal adhesion of the cytoplasm to the cell-wall. The cytoplasm is, therefore, not a sac lying against the cell-wall, but is more intimately related to it.

14. During the resting period the chlorophyll masses retain a green color till they disappear. Concurrently an orange-red pigment accumulates in vesicles in the cytoplasm of the animal.

15. To judge from observation of the earlier portion of the digestion period, a plethoric individual would occupy about a week to ten days in digesting its food. It is not sure, however, that digestion proceeds at this rate in the ordinary resting condition, since such individuals as are judged to have been in a resting condition for a much longer time were still crowded with food masses, or masses which appeared to be such. It may be, therefore, that there are two resting forms, one a digesting condition with high vitality and the other a strictly resting condition of low vitality.

16. On entering the resting condition the animal has been seen to contract vigorously. This contraction was sufficient to cause the ectoplasm to burst, resulting in an eruption of contained material.

17. The hyaline border, evident in the early portion of the resting condition, gradually disappears. Meanwhile contractile vacuoles are active. The hyaline border is not here taken to mean ectoplasm, but a deeper zone including but more extensive than it.

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Note (November, 1926).—I am informed by Russian colleagues, Maximow and Issatschenko, that Gobi did much work on Vampyrella, but I have failed to see his papers. An alleged complete bibliography kindly furnished by the New York Public Library fails to reveal them.

EXPLANATION OF PLATES

PLATE XXV

Vampyrella lateritia and Spirogyra (life-photographs)

1. Animal walking, viewed from above. Note long lateral curved pseudopodia.

2. Animal just leaving an empty cell. Knobbed and forked pseudopodia, which are rapidly extended and withdrawn.

3. Animal beginning to effect an opening in a cell (with inwardly bulging end-wall). Short, pin-head pseudopodia. The rounded oral area of the animal is indicated.

4. Animal showing the receptive vacuole with a very thin wall above. Clumps of chloroplast from a former meal in the cytoplasm; ejecta forming a cloud above the surface (upper left-hand).

5. A similar case, swallowing less advanced than in Figure 4. Ejecta showing as a cloud of granules just beyond the limb. Trabeculae in the chloroplast.

6. The same case as Figure 5, feeding completed.

7. Another case, feeding completed. Strands of Spirogyra cytoplasm sticking to walls of cell.

8. Empty cell just after the animal left it. Ejecta remaining around the hole.

9. Case showing a crowd of granules (ejecta) just after ejaculation. Ends of the Spirogyra cytoplasm seen just before close of ingestion.

10. Resting condition, attached to a Spirogyra filament.

11. The same, plasmolysed with sucrose to show the two membranes.

12. Another example of resting condition.

13–17. Series of photographs of the same animal. Progress of digestion.

13–14. Fifteen minutes apart. Note change in topography in the hyaline zone, due to activity of contractile vacuoles. October 30, 1925.

17. Food vacuoles partly filled with sap. November 3, 1925.

PLATE XXVI

Vampyrella lateritia and Spirogyra (life-photographs)

1–4. Series of the same animal walking (*quasi* upwards). Note position of long pseudopodia. Absence of rolling.

5. Animal leaving, advancing from the filament to the supporting glass. Note long curved pseudopodium.

6–17. Series from motion picture film (about twenty minutes from first to last).

6. End-walls of Spirogyra cell bulging inward. Marginal pseudopodia can be seen.

7. Less than one second before the end-walls reached their maximum distention and disarticulation took place.

8. Less than one second later. Disarticulation has intervened accompanied by the bursting of the cell-wall at the point of hydrolization. Note the bulging of the animal on one quadrant in consequence.

9. Swelling of the chloroplast, which begins to be withdrawn.

10. Chloroplast still more swollen and beginning to bead off. Endoplast only withdrawn from left end of cell.

11–13. Clumping of chloroplast during withdrawal.

14. Adhesion of ectoplasm to *quasi* left-end cell-wall.

13–14. Time-interval less than one second between 13 and 14.

13–16. Pseudopodia have disappeared.

15. Ectoplasm has now broken away.

16. Feeding completed.

17. Animal moves away.

PLATE XXVII

Vampyrella lateritia and Spirogyra (life-photographs)

1–3. First contact, session and expansion due to bulging out of hydrolysed area of Spirogyra cell-wall.

4. Here the hydrolysed area of the cell-wall bulges dome-shaped into the animal. In consequence of the release of pressure, the end-walls bulge inward because of pressure of adjacent cell. Forked, pin-head pseudopodia. The chloroplast has begun to swell (cf. with that in normal, adjacent cell).

5–18. Series from a continuous motion-picture film.
Time-intervals: 5– 8, 4 minutes
8–10, 6 minutes
10–11, 2 minutes
11–12, 3.25 minutes
12–18, 5 minutes

5. Same condition as the animal in Figure 3. Less than one second before bursting of the hydrolysed area which, accompanied by disarticulation, has occurred in Figure 6.

5–8. Rib-like ridges can be seen in the receptive vacuole.

8. Readjustment of size has taken place.

12–18. Loss of two thirds of volume takes place during this interval, the approximate original size being reached. Note that in Figure 18 the same Spirogyra cells appear as in the previous figures.

PLATE XXV

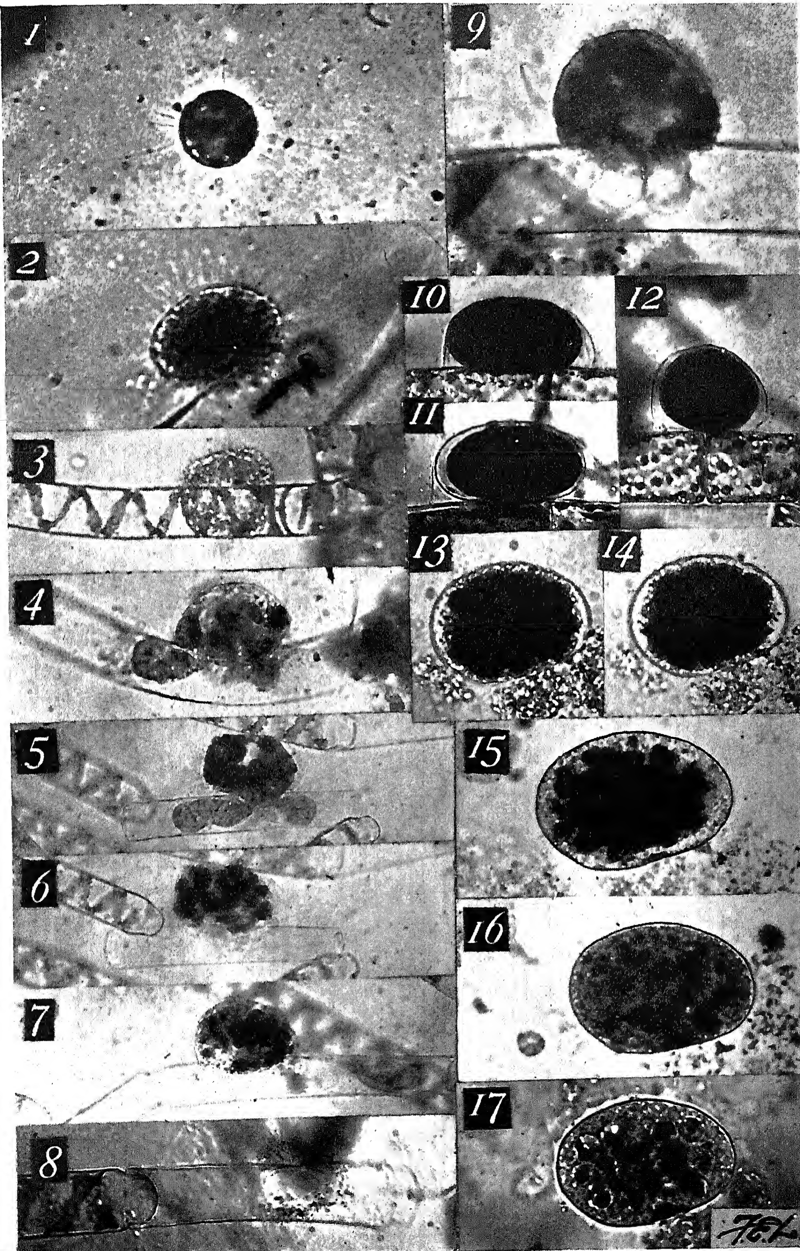


PLATE XXVI

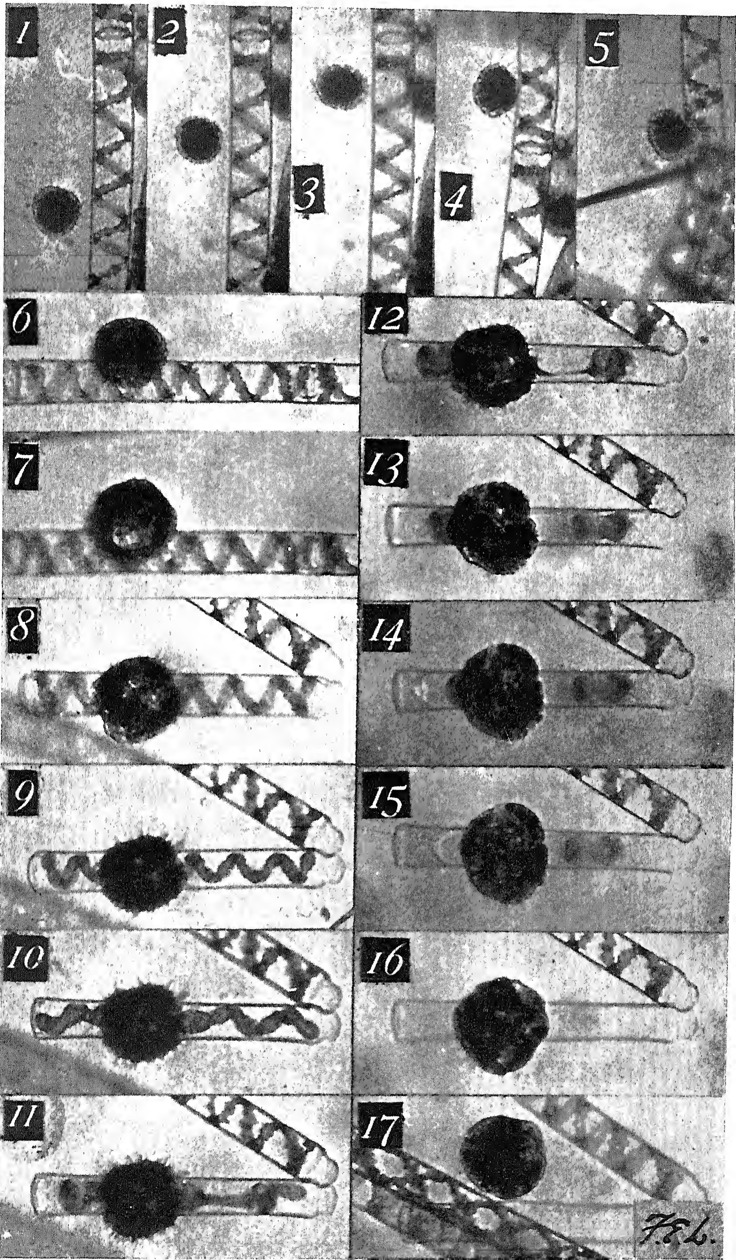
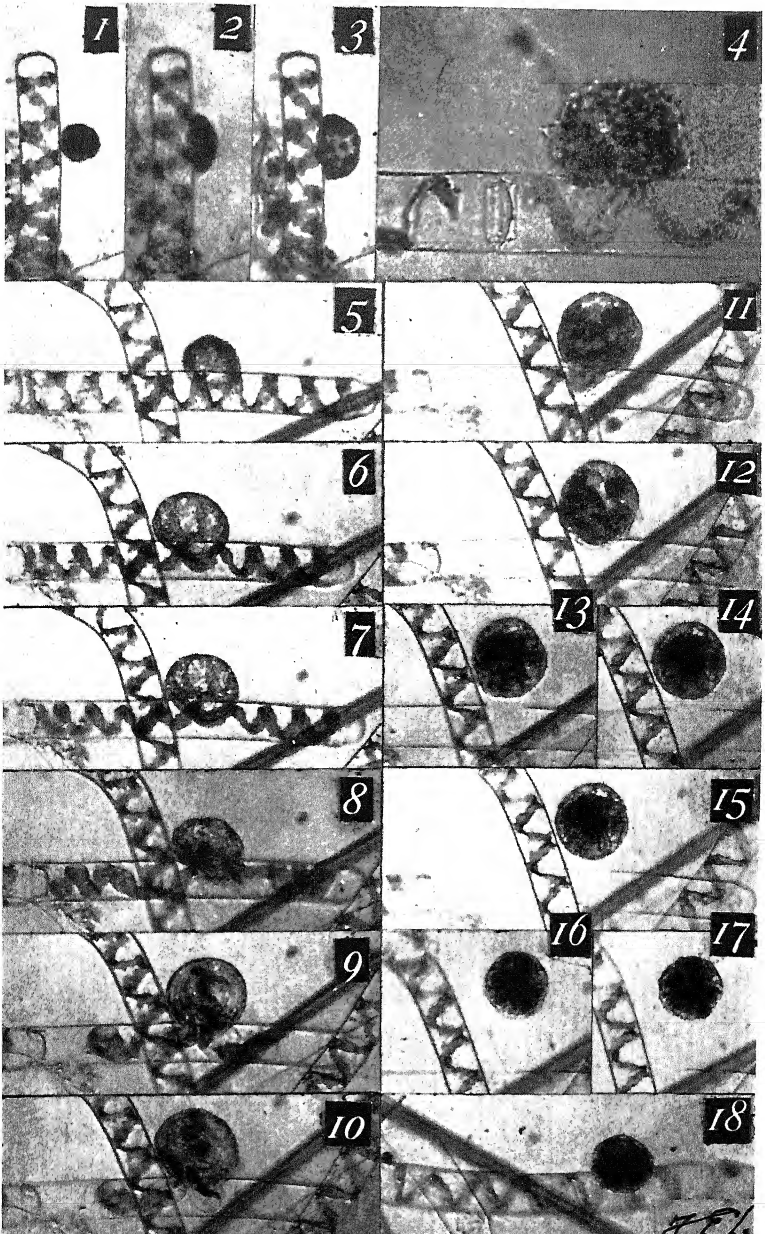


PLATE XXVII



TEMPERATURE-CONTROLLED VARIATION IN THE GOLDEN SHINER, *NOTEMIGONUS CRYSOLEUCAS* *

LEONARD P. SCHULTZ

THIS study of the variation in the number of anal rays in *Notemigonus crysoleucas* (Mitchill), illustrated in Plate XXVIII, Fig. 1, was suggested by Mr. Carl L. Hubbs, of the University of Michigan, who had already given the subject some attention. To him I am especially indebted for carefully reading and criticizing my manuscript, for suggesting many changes and neatly constructing one of the tables, besides furnishing many of the counts for various sections of the United States. My thanks are due also to Mr. A. C. Weed, who kindly sent counts for Indiana, Illinois, Florida, Ontario, New York, Georgia, Louisiana, Texas, Maryland and Michigan and granted permission to publish the data; to Mr. J. R. Dymond, of the University of Toronto, who provided specimens from the northern range of Notemigonus, two of which have been photographed; to Mr. H. W. Fowler, of the Academy of Natural Sciences of Philadelphia, who sent a large number of specimens from the Atlantic Coast states; and to the authorities of the following institutions for permission to publish these data on their material: the American Museum, the National Museum, the Field Museum and the Museum of Zoölogy of the University of Michigan.

In this study particular attention is paid to the relationship between the variation in the number of anal rays and the temperature during the developmental season. It is concluded that the relation is a close one; in fact, that the temperature is the chief cause of the variation in the number of rays in the anal fin.

* Contribution from the Department of Zoölogy, University of Michigan.

The principal anal rays were counted. The first of these, which is unbranched, is the last of two or more simple rays. All the rest are branched; the last one is forked to its base, but is counted as a single ray. The variation counts have been accorded the usual statistical treatment. In the tables, N equals the number of specimens, M, the arithmetic mean, E_M, the probable error, plus or minus, of the mean. This value is obtained by dividing the product of the standard deviation times 0.6745 by the square root of N–1. Two values are looked upon as statistically significant if the difference between the means is more than three times the probable error of the difference. This last value is determined by extracting the square root of the sum of the squares of the two probable errors involved. Pearson's coefficient of correlation is equal to *r*. One of the correlations determined (Table I) is not of statistical significance, being much less than three times its probable error.

Notemigonus crysoleucas, or the golden shiner, occurs throughout Eastern United States and Canada. It is one of the most common minnows of the ponds, lakes and more sluggish streams. It shows a marked adaptability to temperature differences, living in cool trout streams in the north and in the warm lakes of the far south. It ranges from New Brunswick and Quebec southward to Florida; westward through the Great Lakes Region to North Dakota, and through the Gulf drainage basin to the Neuces River of Texas.

It is not uncommon to find a variation of five or even more rays in a series from a single lake or stream. Thus in the Au Sable River below Foote Dam, Michigan, the species shows an extreme variation of 8 to 14 anal rays; in Saginaw Bay, 8 to 13 rays; at Beachton, Florida, 14 to 19 rays; in the Calumet River at Clark, Indiana, 9 to 14 rays. The difference between the extreme variants of one locality is thus quite striking, and involves the form of the fin as well as the number of rays. This is shown in Plate XXVIII, on which are illustrated the anal fins of two specimens from Lake Abitibi, Ontario, at the extreme northern end of the range of this species. Figure 2 shows a long fin with 15 rays, a number characteristic of the species at the op-

posite end of its distribution and variation. Figure 3 illustrates a short fin with 11 rays, a number more usual for the locality.

Hubbs (1926) indicated that the segmental features of many fishes are highly variable, and that the number of segments may be increased in cool waters, in which development is retarded, and decreased in waters of higher temperature, in which development is accelerated. He cited the variation in the number of anal rays in Notemigonus as one of the unexplained but valid exceptions to the general tendency. I find that there is no significant correlation between the anal rays and the number of caudal vertebrae [1] in this minnow (see Table I), and probably no geographical variation in vertebral number. The one specimen of the southeastern form with an increased number of anal rays (this specimen has 15) shows 18 caudal vertebrae, the modal number in Michigan.

TABLE I

CORRELATION BETWEEN ANAL RAYS AND CAUDAL VERTEBRAE IN NOTEMIGONUS

Counts made on specimens from Roe Lake, Michigan

Number of caudal vertebrae	Number of principal anal rays				
	11	12	13	14	
17	1	8	4	–	number of cases
18	11	120	68	3	
19	4	43	24	–	
20	–	2	–	–	
r equals -0.11	The probable error of r is equal to ± 0.05				

[1] The number of caudal vertebrae was used because (1) variation in this part of the column is greater than in the abdominal portion, (2) the anal rays subtend the caudal vertebrae, and (3) these vertebrae are more readily and accurately counted than those near the head.

Hubbs (1921) found that in the southeastern subspecies, *boscii*, the extreme variation in number of scales in the lateral line ranges between 42 and 53, with the mean at 46. The range given for *crysoleucas* proper is from 42 to 53, with the mean at 47 instead of 46. These figures show little if any difference in

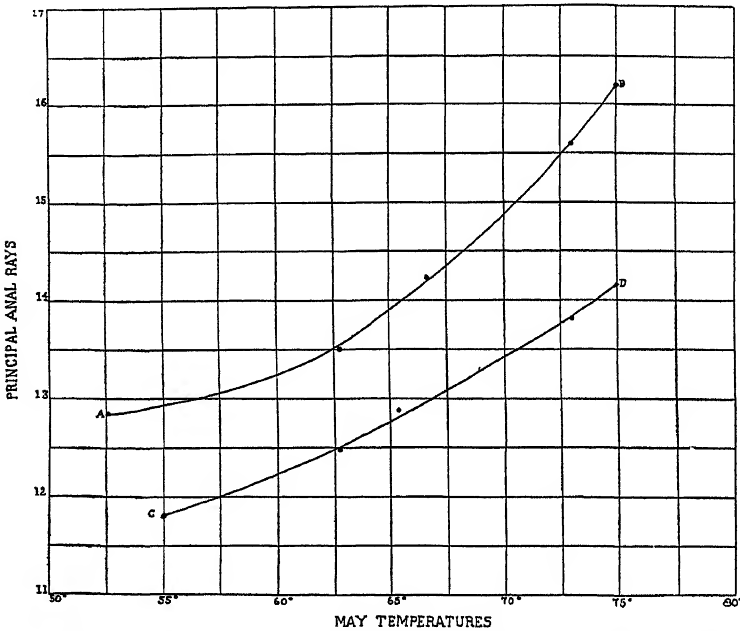


FIG. 16. Chart showing the correlation between anal ray number in Notemigonus and May temperatures

When the May temperatures and the average number of anal rays of *Notemigonus crysoleucas* are plotted both for the Atlantic Coast (shown by line AB) and the western edge of the range (shown by line CD), the close relationship in number of anal rays and temperature is seen to be nearly proportional in both regions.

scale characters. This suggests further that the species shows no sharp racial difference in number of vertebrae, for the number of scales in the lateral line of fishes usually varies proportionally with the vertebrae.

In Notemigonus the number of anal rays averages highest in Florida and decreases toward the north and northwest. Although the variation in anal rays in this minnow shows a reversed gradient with reference to temperature, the correlation is nevertheless fairly close (see Fig. 16). This can be shown by

FIG. 17. Map showing the areas occupied by the races of *Notemigonus crysoleucas* and the average May temperatures

The numbers underlined indicate roughly the areas occupied by races of Notemigonus. The broken lines are the average May temperatures (isotherms). It will be noticed that there is a close relationship between the decrease northward in anal ray number and a decrease of temperature.

plotting the anal ray counts on a map of Eastern United States (Fig. 17) on which the May isotherms[2] have been drawn. The

[2] The isotherms were copied from the map published by the U. S. Weather Bureau in the *Monthly Weather Bureau Review*, 49 (1921): 596–597.

data for May are used because Notemigonus spawns chiefly during this month, except possibly in the northern part of its range, where specimens containing eggs were taken toward the end of June. The water temperatures follow the air temperatures, only roughly of course, but we have no better values. The number of fin rays is fixed within a few days after the beginning of development. The variation in anal rays corresponds fairly well with the position of the May isotherms, for the average number decreases toward the north both along the Atlantic Coast and in the Mississippi Valley (Table II, A and B).

TABLE II

North and South Variation of Notemigonus throughout Its Range
(A) along the Atlantic Coast

Locality	Principal anal rays											N	M	E_M
	9	10	11	12	13	14	15	16	17	18	19			
North Rose, New York.. .			5	25	30	9	1					70	12.66	±.07
Eastern N. Y.; N. H.; Mass. to Nova Scotia...			1	3	14	–	1					19	12.84	±.11
Pa., Atlantic drainage basin and New Jersey........			1	27	181	119	31	4				363	13.45	±.03
Delaware	1			6	31	24	7					69	13.41	±.08
Md., D. C. and Potomac River			1	18	85	79	17	2				202	13.34	±.04
Virginia, a mountain stream		1	1	3	2							7	11.86	±.22
Virginia, coastal plain.....					2	4	2	1				9	14.22	±.21
North Carolina...........						2	1	2				5	15.00	±.30
S. C. and Ga. to north....						4	17	13	9			43	15.62	±.09
Florida and Georgia near border						5	24	58	48	16	1	152	16.32	±.05
Totals..................	1	1	9	82	345	246	101	80	57	16	1	939	13.96	

(B) Along the Mississippi Valley and Great Lakes

Locality	Principal anal rays												N	M	E_M
	8	9	10	11	12	13	14	15	16	17	18	19			
Wis., Minn., N. D. .				33	51	4							88	11.67	± .04
Iowa				3	3	2	1						9	12.11	± .24
Michigan streams . .	1	–	13	351	941	211	12						1529	11.90	± .01
Michigan lakes . . .			10	216	943	373	28	1					1571	12.12	± .01
Ontario, Canada, vicinity			1	2	39	20	1	1					64	12.32	± .07
Illinois			1	10	73	60	14	1					159	12.49	± .04
Indiana		1	1	11	62	40	10	1					126	12.37	± .05
Ohio, Lake Erie drainage basin of Pa.				3	7	8	3						21	12.52	± .14
Mo. and Oklahoma .				1	12	11	8	1					33	12.88	± .11
Texas						6	5	2					13	13.69	± .14
Louisiana, Arkansas					2	9	14	8	1				34	13.91	± .11
Alabama								1					1	15.00	.—
Florida, Georgia at border							5	24	58	48	16	1	152	16.32	± .05
Totals	1	1	26	630	2133	744	101	40	59	48	16	1	3800	12.25	

The correlation is close — the northward decrease in ray number is roughly proportionate to the drop of temperature — east of the Appalachian Mountains as well as to the west of them (Fig. 16). In addition, the number of rays decreases westward along the same isotherms (Table III). The lines joining areas in which the anal ray numbers correspond are deflected southward to the west. This southward deflection is roughly in line with the main axis of ice movement, a fact which suggests that glaciation may have caused the irregularity in geographical correlation between temperature and anal ray number. This hypothetical explanation involves the assumption that the ice movement forced southward the preglacial northern race with low anal ray number, and then induced the hybridization of this race with a southern preglacial race having a high number of rays.

TABLE III

VARIATION OF NOTEMIGONUS EAST TO WEST THROUGHOUT ITS RANGE

	Average anal rays		Average anal rays
Far South		*Middle North*	
Florida Georgia	16.32	Pennsylvania New Jersey	13.45
Alabama	15.00	Pennsylvania at Lake Erie Ohio	12 52
Arkansas Louisiana	13.91	Indiana	12.37
Texas	13.69	Illinois	12.49
Middle South		Iowa	12.11
N. Carolina Virginia	14.50	*Far North*	
Missouri Oklahoma	12.88	Eastern New York, Nova Scotia	12.94
		North Rose, New York	12.66
		Ontario, Canada	12.32
		Michigan	12.00
		Wisconsin Minnesota North Dakota	11.67

The correlation between anal ray number and temperature in Notemigonus is shown in other ways than by the general geographic trend of the variation. In Virginia, for example, the anal rays are distinctly fewer in the cooler mountains than in the warmer regions toward the coast (Table IV).

TABLE IV

VARIATION OF NOTEMIGONUS IN VIRGINIA

Locality	Principal anal rays							N	M	E_M
	10	11	12	13	14	15	16			
Mountain stream, Roanoke..	1	1	3	2	–	–	–	7	11.86	± .217
Coastal plain streams.......	–	–	–	2	4	2	1	9	14.22	± .207

In the Great Lakes proper Notemigonus occurs only in Lake Erie and in Saginaw Bay, an arm of Lake Huron. Elsewhere it does not inhabit the open lakes proper, but is confined to the warmer shore lagoons. In the lakes proper, I find that the Lake Erie race has more anal rays than the Saginaw Bay race. The difference is statistically significant, because it is more than three times the probable error of the difference of the mean.

TABLE V

VARIATION OF NOTEMIGONUS IN THE GREAT LAKES

Locality	Principal anal rays							N	M	E_M
	8	9	10	11	12	13	14			
Saginaw Bay *..........	1	2	3	30	74	21	–	131	11.89	±0.06
Lake Erie †............				19	62	41	3	125	12.23	±0.04

* At Pinconning, Michigan

† In Lake Erie proper at Erie, Pennsylvania, and at East Harbor, Ohio; in the estuary at the mouth of River Raisin, near Monroe, Michigan, and in the Detroit River and Lake St. Clair

Now taking samples from lagoons and estuaries, along the shores of the Great Lakes, I find that the lots from the warm shallows of Jackson Park Lagoon in Chicago have a higher average number of anal rays than those at Cheboygan, Michigan, doubtless also a higher temperature. The difference between the means (0.63) is 7 times the probable error of the mean (± 0.09).

TABLE VI

VARIATION OF NOTEMIGONUS IN THE GREAT LAKES LAGOONS

Locality	Principal anal rays					N	M	E_M
	11	12	13	14	15			
Lagoon at Cheboygan, Michigan..	–	14	4	–	–	18	12.22	±0.07
Jackson Park Lagoon, Illinois.....	1	20	35	10	1	67	12.85	±0.06

The golden shiner is locally abundant in streams throughout the State of Michigan. The streams average much colder than the lakes. In apparent correlation with this difference in temperature, the number of anal rays averages slightly fewer in Michigan streams than in the lakes (Table VII). This difference is statistically significant.

TABLE VII

VARIATION OF NOTEMIGONUS IN MICHIGAN LAKES AND STREAMS

	Principal anal rays								N	M	E_M
	8	9	10	11	12	13	14	15			
Lakes			10	216	943	373	28	1	1571	12.12	±0.01
Streams	1	–	13	351	941	211	12	–	1529	11.90	±0.01

The number of anal rays in the streams and lakes of Michigan is subject to much variability (Tables VIII and IX). Some of this variability may be correlated with the temperature, but some probably is not. For instance Rush Lake in Huron County (now drained) was a warm shallow marshy lake, yet in it the rays averaged only 11.57. Another example is found in the Black River drainage basin, where in all the lakes the anal rays average low. But, nevertheless, with these exceptions included, the average number of anal rays is smaller in cooler waters and greater in those of a higher temperature.

TABLE VIII

VARIATION OF NOTEMIGONUS IN MICHIGAN STREAM SYSTEMS

LOCALITY	Principal anal rays							N	M
	8	9	10	11	12	13	14		
Taquamenon system........ ...				10	23	4	–	37	11.84
Creek below Algonquin....... .				5	14	8	1	28	12.19
Thunder Bay system...........			2	35	109	13		159	11.84
Devil River system......... ...				17	26	8		51	11.82
Au Sable system.............	1		5	123	312	44	2	487	11.80
Manistee system				7	46	20	3	76	12.25
Saginaw system................				11	50	9		70	11.97
Southwestern streams *				1	23	2		26	12.04
Southeastern streams †........			6	142	338	103	6	595	11.93

* Silver Creek, Cass County; Dowagiac River; Paw Paw River; Bear Creek, St. Joseph County

† Tributary to St. Clair River; the Huron River and many of its tributaries

TABLE IX

VARIATION OF NOTEMIGONUS IN MICHIGAN LAKES

Lakes	Principal anal rays						N	M
	10	11	12	13	14	15		
Killhain, Luce Co.	3	35	165	54	1	–	258	12.06
Twin, Luce Co.	–	1	2	1	–	–	4	12.00
Bodi, Luce Co.	3	17	53	32	4	–	109	12.16
Lancaster, Cheboygan Co.	–	1	3	2	–	–	6	12.17
Douglas, Cheboygan Co.	–	–	2	–	–	–	2	12.00
Indian River,* Cheboygan Co.	–	2	21	6	–	–	29	12.14
Osmunds, Cheboygan Co.	–	17	58	8	–	–	83	11.89
S. Tomahawk, Montmorency Co.	2	39	87	13	1	–	142	11.80
Valentine, Montmorency Co.	–	11	22	2	–	–	35	11.74
Presque Isle Co. lakes	–	–	3	–	–	–	3	12.00
Lockwood, Montmorency Co.	–	5	7	1	–	–	13	11.69
Snyder, Alpena Co.	1	2	6	–	1	–	10	11.80
Devil, Alpena Co.	–	2	19	3	–	–	24	12.04
Roe, Alcona Co.	–	21	225	153	8	–	407	12.36
Bradford Lakes, Otsego Co.	–	4	10	2	–	–	16	11.88
Bass Lakes, Otsego Co.	–	2	47	12	–	–	61	12.17
Linn, Otsego Co.	–	–	2	1	–	–	3	12.34
Jones, Crawford Co.	–	–	9	6	–	–	15	12.40
St. Helens, Roscommon Co.	–	8	43	3	1	–	55	11.94
Rush, Huron Co.	–	16	18	1	–	–	35	11.57
Barber, near Flint	–	1	1	–	–	–	2	11.50
Walnut, Oakland Co.	1	13	51	11	–	–	76	11.95
Dewey, Cass Co.	–	13	58	48	12	1	132	12.47
Sister Lakes, Ann Arbor	–	6	31	14	–	–	51	12.16

* This connects two large lakes, Burt and Mullet, and is lake-like.

This study of the principal rays in the anal fin of Notemigonus indicates that the golden shiner is differentiated into races, which seem to occupy more or less definite ranges. There is a graded decrease of anal ray number from Florida (average 16.33) northward and westward to Wisconsin and Minnesota (average 11.67). The variation is nearly proportional to the May temperatures, during which month the number of

anal rays is fixed in development. There is also a westward decrease in the number of anal rays. As a result the variation is concentric about Florida. This westward decrease may have been caused by glaciation.

Within certain sections of the country, as in Virginia and Michigan, the number appears to be correlated with the temperatures of the water during development, for a higher number developed under the warmer temperatures. This fact, together with the southward increase, shows that temperature controls to a great extent the raciation and variation of Notemigonus. The environmental correlation, although close, is opposite to that usually observed, for in most fishes the segmental structures and fin rays increase in number toward colder rather than, as in the present case, toward warmer waters. It is shown, however, that the number of caudal vertebrae and the number of scales in the lateral line present no clear geographical variation and no correlation with the variation in the anal fin.

University of Michigan

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APPENDIX: DATA IN DETAIL

The figures in parentheses indicate the number of specimens for each anal ray number; thus 15 (1) means one count of 15 anal rays.

ALABAMA. — Black Warrior River at Tuscaloosa, 15 (1).

ARKANSAS. — Greenway, 13 (1), 15 (1); Big Bay, 14 (2).

DELAWARE. — Wilmington, 9 (1), 13 (4), 14 (4), 15 (1); Harmons Creek in New Castle County, 13 (5), 14 (3), 15 (1); Brandywine Creek at Wilmington, 12 (6), 13 (22), 14 (17), 15 (5).

DISTRICT OF COLUMBIA. — Anacostia River, 11 (1), 12 (2), 13 (22), 14 (21), 15 (6).

FLORIDA. — A count by Jordan and Meek, 1885, 17 (1); Lake Monroe, 14 (4), 15 (8), 16 (18), 17 (14), 18 (1); Joslin Creek, 15 (3), 16 (2); St. Johns River, 18 (1); Sanford, 15 (1), 16 (2), 17 (4), 18 (1); Gainesville, 15 (4), 16 (5), 17 (2); unknown locality of Florida, 16 (1).

GEORGIA. — Jordan and Meek, 15 (1); Waynesborough, 14 (1), 15 (2), 16 (3), 17 (1); Macon, 15 (1), 16 (1), 17 (3); Ocmulgee River, 14 (3), 15 (4), 16 (6), 17 (1); Millen, 15 (2), 16 (1); Beachton, 14 (1), 15 (8), 16 (30), 17 (27), 18 (13), 19 (1).

ILLINOIS. — Jordan and Meek, 13 (1); Berwyn, in the Des Plaines River, 10 (1), 11 (2), 12 (11), 13 (6), 14 (1); Jackson Park Lagoon, Chicago, 11 (1), 12 (20), 13 (35), 14 (10), 15 (1); Dead River at Beach, 11 (1), 12 (1); Momence, 13 (1); Hickory Creek, Alpine, 12 (4); tributary to Des Plaines River, Chicago Ridge, 11 (2), 12 (6), 13 (6), 14 (2); Willow Springs, 11 (4), 12 (31), 13 (11), 14 (1).

INDIANA. — Pikeville, 10 (1), 11 (3), 12 (5), 13 (8), 14 (3); Lake George, 12 (2), 13 (1), 15 (1); Wolf Lake, 12 (2), 13 (1), 14 (1); Clark, Calumet River, 9 (1), 11 (2), 12 (14), 13 (11), 14 (2); Trail Creek, La Porte County, 11 (1), 12 (5); Wolf Creek, Bartholomew County, 12 (2), 14 (1); Southern Indiana, 14 (1); White River Bartholomew County, 13 (1); Turkey Lake, 13 (1); Tippecanoe Lake, 12 (1); Calumet River, Dune Park, 12 (4), 13 (2); Hamilton Lake, 11 (5), 12 (27), 13 (15), 14 (2).

IOWA. — Dumont, Cedar River, 11 (1), 12 (1), 13 (2), 14 (1); Ames, 11 (1); Maquoketa, 11 (1), 12 (2).

LOUISIANA. — Jordan and Meek, 1885, 13 (1); Slidell, 13 (7), 14 (10), 15 (4), 16 (2); Bayou La Comb, pond, 12 (2), 13 (7), 14 (12), 15 (7), 16 (1).

MARYLAND. — Jordan and Meek, 1885, 14 (1); Willards, 13 (1), 14 (2), 15 (1); Plum Point Creek, 13 (4), 14 (1); Mattawoman Creek, 13 (1), 14 (6); Muddy Creek, 13 (2), 14 (2), 15 (1); Elk Creek, 12 (1), 13 (1), 14 (1); Taurel, 12 (1), 13 (6), 14 (11), 15 (4), 16 (1); Big Bohemia Creek, Cecil County, 12 (14), 13 (47), 14 (26), 15 (3), 16 (1).

Massachusetts. — Woods Hole, 13 (1); South Hadley Falls, 13 (3), 15 (1); Newburyport, 13 (1).

Michigan.[3] — Lagoon at Cheboygan, 12 (14), 13 (4); Saginaw Bay, at Pinconning, 9 (1), 10 (3), 11 (13), 12 (36), 13 (11); River Raisin, Monroe, 11 (10), 12 (35), 13 (26), 14 (1); Detroit River, 11 (1), 12 (3), 13 (1); Lake Erie, 11 (8), 12 (26), 13 (12); Straits of Mackinac, 12 (12), 13 (4); Lake St. Clair, 12 (2), 13 (1); Monroe Piers, Lake Erie, 11 (1), 12 (5), 13 (5), 14 (1); Loud Pond, Au Sable River, 10 (1), 11 (59), 12 (148), 13 (18); Foot Dam, Au Sable River, 8 (1), 11 (9), 12 (28), 13 (8), 14 (1); Alcona Pond Dam, Au Sable River, 11 (7), 12 (16), 13 (2); Five Channels Dam, Au Sable River, 11 (3), 12 (13), 13 (1); Mio Pond, Au Sable River, 12 (8), 13 (2); Cooke Dam, Au Sable River, 10 (4), 11 (38), 12 (74), 13 (10), 14 (1); East Branch of Au Sable, 13 (2); Au Sable, Iosco County, 11 (4), 12 (20), 13 (1); South Branch, Au Sable, 11 (1), Au Sable, Oscoda, 12 (1); Au Sable River, 11 (2), 12 (4); Devil River, North Branch, 11 (9), 12 (7), 13 (4); Devil River, mouth, 11 (1), 12 (3); Devil River, Alpena County, 11 (7), 12 (16), 13 (4); Thunder Bay River, Alpena County, 10 (2), 11 (29), 12 (97), 13 (11); Sunken Lake, Thunder Bay River, 11 (6), 12 (11), 13 (2); Deer Creek, Alpena County, 12 (1); Saginaw drainage basin, Pine River, 12 (1); Pigeon River, Huron County, 11 (5), 12 (21), 13 (4); ditch near Akron, 11 (3), 12 (14), 13 (4); creek in Gratiot County, 11 (1), 12 (3); ditch, Fairgrove, 12 (1); Shiawassee River, 13 (1); Oxbow, Freeland, 11 (2), 12 (10); Bear Creek, St. Joseph County, 12 (1), 13 (1); tributary to Dowagiac River, 12 (1); Paw Paw River, 12 (4); Saginaw Bay, Pinconning, 8 (1), 9 (1), 11 (17), 12 (38), 13 (10); Silver Creek, Cass County, 11 (1), 12 (17), 13 (1); Chalmers Creek, Huron County, 10 (1), 11 (1), 12 (13), 13 (6); Arm Creek, Huron River, 11 (2); tributary to St. Clair River, 10 (1), 11 (3), 12 (8), 13 (1); Huron River at Geddes, 10 (4), 11 (136), 12 (317), 13 (96), 14 (6); Manistee River, Junction Dam, 11 (4), 12 (41), 13 (20), 14 (3); Manistee River, Manistee Lake, 11 (3), 12 (5); Gimlet Creek, Luce County, 11 (6), 12 (16), 13 (3); Henry River, Luce County, 11 (4), 12 (5), 13 (1); East Branch of Taquamenon River, 12 (2); creek below Algonquin, 11 (5), 12 (14), 13 (8), 14 (1).

Minnesota. — Cass Lake, 12 (1); Red River, 12 (1).

Missouri. — Blackwater Creek, Saline County, 12 (2); Dixon, 12 (1), 13 (1), 14 (3), 15 (1).

New Hampshire. — Locality unknown, 12 (1); Umbagog, 13 (1).

New Jersey. — Muddy Creek, Cumberland County, 13 (2), 14 (8), 15 (5), 16 (1); unknown locality, 13 (4), 14 (2); Alloway, Deep River, 13 (1), 14 (1).

New York. — Cape Vincent, 13 (1); Van Cortlandt Park, New York City, 13 (2); Echo Lake, Orange County, 11 (1), 12 (1), 13 (1); Highland Falls, 12 (1), 13 (3); North Rose, 11 (5), 12 (25), 13 (30), 14 (9), 15 (1).

[3] For additional data see Tables VIII and IX.

NORTH CAROLINA. — Raleigh, 14 (1), 15 (1); Greensborough, 14 (1), 16 (2).

NORTH DAKOTA. — Jamestown, 12 (1).

NOVA SCOTIA. — 13 (1).

OHIO. — Blanchard River, Findlay, 12 (3); Ross Lake, Cincinnati, 11 (1), 13 (2); Hicksville, 12 (1), 13 (2); Loveland, 12 (1); East Harbor, Lake Erie, 13 (1), 14 (1); Fremont, 14 (1); Vermillion River, 12 (1), 13 (1); Lake Erie, Pennsylvania drainage basin, 11 (2), 12 (1), 13 (1).

OKLAHOMA. — Wister, 13 (1); Canadian River, Norman, 11 (1), 12 (8), 13 (9), 14 (4); near Okmulgee, 12 (1), 14 (1).

ONTARIO. — Bale, 14 (1); Gravenhurst, 10 (1), 12 (14), 13 (14); Dedricks Creek, 12 (5), 13 (1); Big Creek, Norfolk, 12 (1); Union Pond, 12 (1); Big Creek, Port Rowan, 12 (8), 13 (5); Go Home Bay, 12 (2); Swamp Lake, 12 (1); Sheas Bay, Abitibi, 11 (2), 12 (7), 15 (1).

PENNSYLVANIA. — Helfrick's Spring, Lehigh County, 14 (2); Valley Creek, Montgomery County, 12 (1), 13 (3); Montgomery Creek, 13 (10), 14 (3); Sandy Run, Holmesburg, Philadelphia County, 13 (1), 14 (1); Pennybuck Creek, 12 (8), 13 (57), 14 (38), 15 (12), 16 (1); Swamp Creek, Montgomery County, 12 (1), 13 (6), 14 (3); Delaware River, Torresdale, 12 (1), 13 (11), 14 (5), 15 (3); Lime Kiln River, Lehigh County, 13 (7), 14 (2), 15 (1); Scotts Creek, Bucks County, 13 (1), 14 (2); Brandywine Creek, Chester County, 13 (2), 14 (2); Indian River, Lehigh County, 12 (1), 14 (1); Delaware River, Bristol, 12 (1), 13 (30), 14 (27), 15 (4), 16 (2); creek at Hallertown, Northampton County, 12 (1), 13 (2); Cocalus Creek, Lancaster County, 12 (3), 13 (17), 14 (10), 15 (3); Will Creek, Bucks County, 11 (1), 12 (5), 13 (11), 14 (5), 15 (2); Susquehanna River at York, 12 (5), 13 (15), 14 (6).

POTOMAC RIVER. — 13 (1), 14 (1).

SOUTH CAROLINA. — Columbia, 15 (7), 16 (2), 17 (4).

TEXAS. — Houston, 13 (2), 14 (4); Arthur, 13 (2), 15 (2); Palestine, 13 (1); Jordan and Meek, 13 (1); Rio Neuces, 14 (1).

VIRGINIA. — Suffolk, 13 (1), 14 (2), 15 (1); Custer Spring, 13 (1), 14 (1); Dismal Swamp, 14 (1), 16 (1); Jordan and Meek, 15 (1); Eight-mile Creek, Roanoke, 10 (1), 11 (1), 12 (3), 13 (2).

WEST VIRGINIA. — Black Creek, Berkley County, 13 (1), 14 (8), 15 (2).

WISCONSIN. — Root River, 11 (3), 12 (5), 13 (2); Oak Creek, 11 (1), 12 (3); Lake Pepin, 12 (2); Manibowish River, Vilas County, 12 (2); Rose Lake, Forest County, 11 (3), 12 (4), 13 (2); Riley Lake, Forest County, 11 (26), 12 (32).

PLATE XXVIII

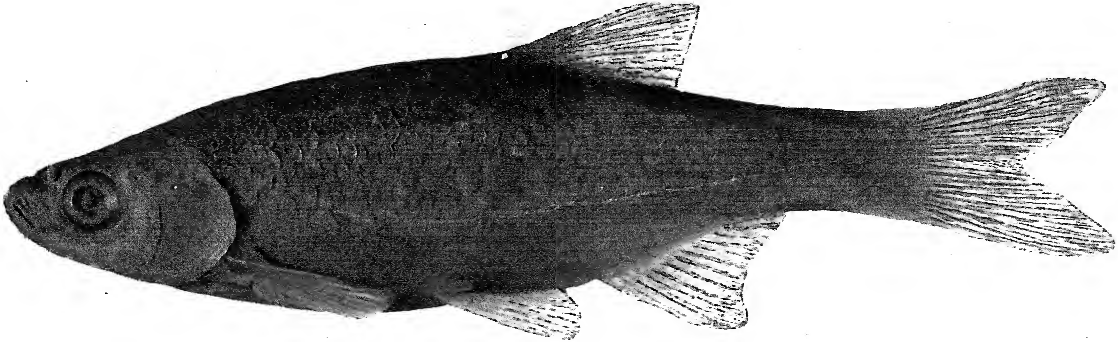

FIG. 1

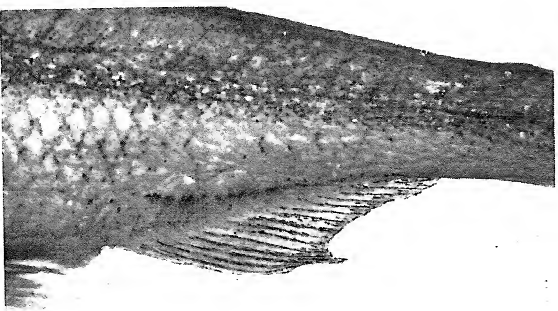

FIG. 2

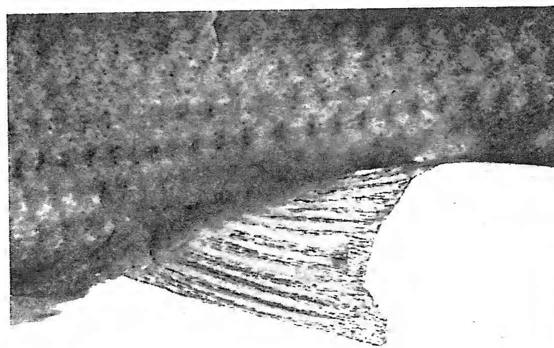

FIG. 3

FIG. 1. *Notemigonus crysoleucas*, a Golden Shiner from Wisconsin FIGS. 2–3. Anal Fin Rays of Two Golden Shiners from Lake Abitibi, Ontario, Canada: Fig. 2 with 15 rays; Fig. 3 with 11

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